African Sharptooth Catfish Feasibility Study

Final Report

2018

agriculture, forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

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Executive Summary

The Department of Agriculture, Forestry and Fisheries (DAFF) Chief Directorate: Aquaculture and Economic Development aims to "*develop a sustainable and competitive sector that will contribute meaningfully to job creation, economic development, sustainable livelihoods, food security, rural development and transformation"* in South Africa. In line with this mandate, research and development has been done on several freshwater and marine species which are important and valuable species to the South African aquaculture sector.

The African sharptooth catfish is a popular species for aquaculture, particularly in Africa, with Nigeria being the largest producer of African sharptooth catfish in the world. Catfish are considered to be a good species for aquaculture because of a few key factors such as:

I. Ability to be grown at high stocking densities, due to their air-breathing ability,
II. High ability to withstand handling stress,
III. It is a highly valued food fish in many African countries,
IV. Fast growth rates have been recorded in various production systems,
V. Resistance to disease, and
VI. Wide tolerance of temperatures and water quality (DAFF & WRC,2010).

South African sharptooth catfish production is predominantly carried out by smallholder producers, with a few key government supported initiatives. In recent years, a shift in production has been identified with less producers growing catfish to market size and more producers focusing on producing catfish fingerlings for the export market. Catfish farms in South Africa are typically located in the Free State, Limpopo, North West, Gauteng, and the Eastern Cape. The African sharptooth catfish industry is dominated by Nigeria, who are currently the leading producer, followed by Uganda. In recent years the catfish industry has seen an increase in production, which can be attributed to the development of farming technology, improved farm management and changing consumer behaviour. The South African catfish market is relatively small, with approximately 100 tons of catfish being produced in 2014. South African producers seem to be focusing more on the production of catfish fingerlings for export as opposed to growing catfish for eating.

The following production guidelines provided in the table below provides a brief overview of a few important factors that should be considered when looking at catfish production in South Africa.

African sharptooth catfish production overview

Optimal Temperature Range	28 – 30°C
Water Conditions	Optimal pH: 6.5 -8.0 Oxygen: 5mg/l or higher Ammonia: 2.3 mg/l Salinity: Larval rearing 0 -2.5 ppt & Hatchery rearing/grow out 4 – 6 ppt
Average cost of fingerlings	R 1,50 per 10-gram fingerling
Average Feed Cost	R 12,00/kg
Typical Food Conversion Ratio (FCR)	1:1:1. Can range from 0.9 to 1:3:1
Stocking density	• All systems <10 g fingerlings: **2150 fish/m³** • RAS/aquaponics/raceway @ 100 g: **45 kg/ m³** • Pond @ 100 g: **1.6 kg/ m³** (initial) OR **3.2 kg/ m³ (final)** • Cage @ 100 g: **6.4 kg/ m³ (final)** • Flow through: **200-300 kg/ m³ (final)**
Typical Survival rate	90% over 8 months
Maximum Marketable size	1000 grams (8 months)

A generic economic model for Catfish was developed through inputs from technical experts, industry stakeholders and peer-review workshops. Key assumptions used in the model are mentioned above, as well as several other production and system related assumptions were incorporated into the model**. An example** of the generic economic model results is illustrated in the table below.

Example: Financial Analysis: Catfish in a Pond System

Production and Financial Assumptions	
Province	Eastern Cape
System	Pond
Minimum Annual Profitable Tonnage	71
Selected selling weight	1000 grams (8 months)
Average farm gate price	R 48/kilogram
Target market	Local Market
Applicant details	Start-up farmer with existing land, no infrastructure, or facilities
Education level	Formal Education (certificate, diploma, degree)
Finance option	Debt/Equity (20%)
Interest Rate	8.25%
Generic Economic Model Results	
Total Capital Expenditure	R 4 691 795,61
Working Capital	R 1 305 304.69
Infrastructure expenditure	R 3 386 490,92
Profitability Index (PI)	1,09
Internal Rate of Return (IRR)	8%
Net Present Value (NPV) over 10 years	R 5 093 973,64
Number of employees (Year 1)	7

From the table above, it can be seen that a pond culture is profitable for the African Sharptooth Catfish in the Eastern Cape when producing a minimum of 71 tons per annum and selling the fish at the average farm gate price of R 48/kg which was identified from the generic economic model. A positive PI of 1.09 was achieved with an IRR of 8%. Pond culture requires fairly low capital expenditure in comparison to other culture systems that require more intensive production equipment and infrastructure. The infrastructure development costs are an estimated R 3 386 490, with the working capital costs of R 1 305 304 required for the first eight (8) months of production when producing 71 tons per annum.

When considering African sharptooth catfish production in South Africa, all six (6) production system prove to be economically viable at various production scales, and when selling the fish at different farm gate prices according to the province. prices. It is clear that African sharptooth catfish production can be profitable in all nine provinces; however, careful consideration should be given to site specific conditions as this will impact on the type of system and profitability achieved.

Disclaimer: *Production information and assumptions in this report may be subject to change over time as certain production variables can be expected to fluctuate. Technical assumptions were utilised from various industry experts and stakeholders. Due to the sensitive nature of information shared by stakeholders, personal details of stakeholders will not be included in the report. Stakeholders will be referenced as "Personal Communication" in the document, and reference list.*

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1. Introduction

1.1. Project Background

In South Africa, aquaculture has been identified as a key economic sector and employment cluster. Various policies, programmes and initiatives have been developed and implemented to assist with the development of the aquaculture sector. In support of aquaculture development, key initiatives such as the National Aquaculture Strategic Framework (NASF), the Aquaculture Development and Enhancement Programme (ADEP), and Operation Phakisa were established. The primary goal of the various policies, programmes and initiatives is to accelerate the growth of the aquaculture industry in order to assume a critical role of supplying fish products both locally and internationally; improving job creation, and contributing to the national economy, among other aspects. The sector has also been identified as a key industry that can impact the development and reindustrialisation of the rural communities and townships in South Africa.

Aquaculture is one of the fastest growing food sectors in the world, yet in South Africa, the sector remains small and underdeveloped despite the high-growth potential offered by the sector. In recent years, South Africa has seen improved access to aquaculture technology, increasing amounts of research and development, as well as support from various government departments. This, coupled with the increasing support and interest in the development of the aquaculture industry, presents opportunities to overcome some key challenges faced mainly by aquaculture producers. Some of these challenges include but not limited to access to suitable production areas, shortage of skills and poor knowledge of production systems, lack of access to markets, as well as poor aquaculture value chain development. Through continued research and development, value chain development, education and skills development and continued support, the South African aquaculture industry shows good growth potential that will prove to be valuable from an economic and social aspect.

This report focuses specifically on African Sharptooth Catfish production in South Africa, and considers the following potential production systems:

I. Recirculating Aquaculture Systems (RAS),
II. Pond culture,
III. Cage culture,
IV. Raceways, and
V. Aquaponics.

In addition to the feasibility study conducted, a generic economic model was developed for the African catfish. The generic economic model is aimed at assisting DAFF, industry stakeholders, role-players, and new entrants to the catfish industry to determine the financial viability of catfish projects in South Africa

1.2. Purpose of the Feasibility Study

This feasibility study will be focusing specifically on the African catfish production and marketing in South Africa. The study will cover the following aspects:

I. The African Catfish background,
II. Geographical location best suited for production,

III. Detailed market assessment to determine the demand and supply of the catfish on a global, regional, and local scale,
IV. Potential barriers to entry, and
V. SWOT Analysis and mitigation measures,
VI. Technical Assessment,
VII. Financial Analysis, and
VIII. Conclusion and Recommendations.

In addition to the feasibility study conducted, a generic economic model was developed for the African sharptooth catfish. The generic economic model is aimed at assisting DAFF, industry stakeholders, role-players, and new entrants to the catfish industry to determine the financial viability of catfish projects in South Africa.

1.3. Feasibility Study Outline

The feasibility study is made up of nine (9) sections. Each section is discussed in more detail below to provide an overview of the report.

- **Section 1:** This section provides a project background together with the main aspects that are covered within the feasibility study.
- **Section 2:** This section focuses on providing a species background, and the key biological and physical characteristics for the African sharptooth catfish.
- **Section 3:** A detailed explanation of the potential production systems that can be used for the African sharptooth catfish in South Africa is provided. These production systems are included in the generic economic model to determine the financial viability of each system.
- **Section 4:** This section looks at the geographical distribution of Catfish in South Africa, and provides a high-level suitability assessment, and identifies key requirements for profitability.
- **Section 5:** This section provides a detailed global, regional, and local market analysis for African sharptooth catfish. Marketing, pricing, demand and supply, and the barriers to entry are key factors to be considered before implementing an aquaculture operation.
- **Section 6:** A SWOT Analysis gives a high-level overview of the Catfish industry in South Africa. Mitigation measures are discussed to address key weaknesses and threats identified.
- **Section 7:** A technical assessment provides a brief overview of key production assumptions and guidelines that can be used for African sharptooth catfish production. These assumptions were used in the development of the generic economic model.
- **Section 8:** This section provides a financial analysis for the potential production systems based on the results obtained from the generic economic model. A high-level cost-benefit analysis is discussed to compare the feasibility of the potential production systems. A best-case scenario is provided to highlight the minimum viable tonnage, recommended selling price and investment potential offered by the potential production systems in the nine provinces.

- **Section 9:** The last section provides a conclusion and recommendations for the growth and development of the African sharptooth catfish industry in South Africa.

2. The African Sharptooth Catfish

2.1. Species Background

The African sharptooth catfish (*Clarias gariepinus)* is a fresh water aquaculture species that is indigenous to the inland waters of much of Africa and they are endemic in Asia Minor, in countries such as Israel, Syria and the south of Turkey. They have been widely introduced to other parts of the world including the Netherlands, Hungary, much of South-East Asia and East Asia. This species can be cultivated in areas with a tropical climate, access to geothermal waters or with the use of heated recirculating water systems.

The African sharptooth catfish is a hardy fish that can be densely stocked in low oxygen waters, making it ideal for culture systems in areas with a limited water supply. They are mostly found in lakes, streams, rivers, swamps, and floodplains, many of which are subject to seasonal drying. The most common habitats are floodplain swamps and pools where they can survive during the dry season(s) due to their accessory air breathing organs. The African sharptooth catfish undertake lateral migrations from the larger water bodies, in which they feed and mature at about the age of 12 months, to temporarily flooded marginal areas in order to breed. These reproductive migrations typically take place shortly after the onset of the rainy seasons. Under good aquaculture practices, the fish can be grown from a 1-gram fingerling to approximately 1 kg fish in eight (8) months, at temperatures ranging between 28 and 30°C. The optimum temperature for growth is around 28 °C (Hecht, et al.,1988). Catfish has several positive qualities, which makes it a good candidate specie for aquaculture. These include:

I. Ability to be grown at high stocking densities, due to their air-breathing ability,
II. High ability to withstand handling stress,
III. It is a highly valued food fish in many African countries,
IV. The fish exhibits fast growth rate in various culture system,
V. Resistance to disease,
VI. It also displays some degree of salinity tolerance, a trait which suggests a possible expansion of its culture to brackish waters,
VII. Wide eating habits (but needs substantial protein) with high feed conversion efficiency, and
VIII. Wide tolerance of temperatures and water quality (DAFF & WRC,2010).

These attributes make the sharptooth catfish a freshwater species with the widest latitudinal range in the world (about 70^0 latitude) (Hecht, et al.,1988). Furthermore, the sharptooth catfish is favoured by many fish farmers as it grows well, and it is easy to breed under high stocking conditions. However, some work is required to develop the market for this fish in South Africa. Some of the disadvantages of catfish as an aquaculture species include:

I. Specialised breeding techniques are required for catfish aquaculture,
II. They can easily escape, if pond culture system is used,
III. Require high-protein, specialised feed products,
IV. The species do not have a wide market acceptance, and
V. Palatability sometimes reduces in larger fish that weigh more the two kilograms.

2.2. Biological Characteristics

The sharptooth catfish is eurytopic (able to tolerate a wide range of habitats or ecological conditions) and inhabits a very wide range of inland water, including streams, rivers, pans, swamps, underground sinkholes, shallow and deep lake, as well as impoundments. They are particularly successful in fast-flowing rivers (Hecht et al., 1988). The sharptooth catfish has all the qualities of an aggressive and successful invasive species. Its high fecundity; flexible phenotype; rapid growth; wide habitat preferences; tolerance to extreme water condition; and the ability to subsist on a wide variety of prey, can devastate indigenous fish and aquatic invertebrate populations.

The species can be readily recognised by the following anatomical features: they have a large-flattened bony head, with small eyes and a terminal largemouth; elongated spineless dorsal fin; no adipose fin; pectoral fin with thick serrated spine, used for defence or crawling on land; and possess four pairs of barbels (whisker-like sense organs) around a broad mouth. Their colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey, while the underside is pale cream to white, (Skeleton,2001). The skin coloration is known to change slightly according to substrate and light intensity in culture systems.

The sharptooth catfish can grow very large, with a maximum reported length of 170 cm (IGFA,2001) and weight of 60 kg (Robins, et al ,1991). They do not possess scales but instead have a slimy layer of mucus for protection, which sometimes makes handling large fish very difficult. Catfish have poor eyesight but use their barbels as taste organs in muddy water or in darkness, to find their position and food. The males can be easily recognized by a distinct sexual papilla located immediately behind the anal opening. This sexual papilla is not present in female fish.

Adult catfish are typically found in quiet waters, lakes, and pools, and prefer shallow and swampy areas with a soft muddy substrate and calmer water. They may also occur in fast flowing rivers. The presence of an accessory breathing organ enables this species to breath air when very active or under very dry conditions. They remain in the muddy substrates of ponds and occasionally gulp air through the mouth. They can swim out of the water, using their strong pectoral fins and spines in search of land-based food or can move into the breeding areas through very shallow pathways. As long as the skin of the fish remains moist, the fish is capable of moving across land in search of water. They are omnivorous bottom feeders and can be fed a variety of feeds. Approximately 70% of feeding activity takes place at night. In general, the sharptooth catfish capture their prey by gulping them with a rapid opening of the mouth and then retaining them either on the gillrakers or fine recurved teeth.

The sharptooth catfish awaits suitable environmental conditions for spawning, which usually takes place in summer (Hecht et al., 1988). They reproduce in response to environmental stimuli such as a rise in water level and inundation of low-lying areas. Spawning events do not occur in captivity and hormone treatment is employed to ensure large-scale production of catfish fingerlings (it is extremely difficult to collect sufficient young catfish for the wild, for culture purposes). The hormones used include Ovaprim, Deoxycorticosterone Acetate (DOCA), Human Chorionic Gonadotropin (HCG), pituitary glands from catfish brooders, common carp, Nile tilapia and even frogs, following specific technical procedures (FAO,2010-2017).

The figure below describes the production cycle of the sharptooth catfish.

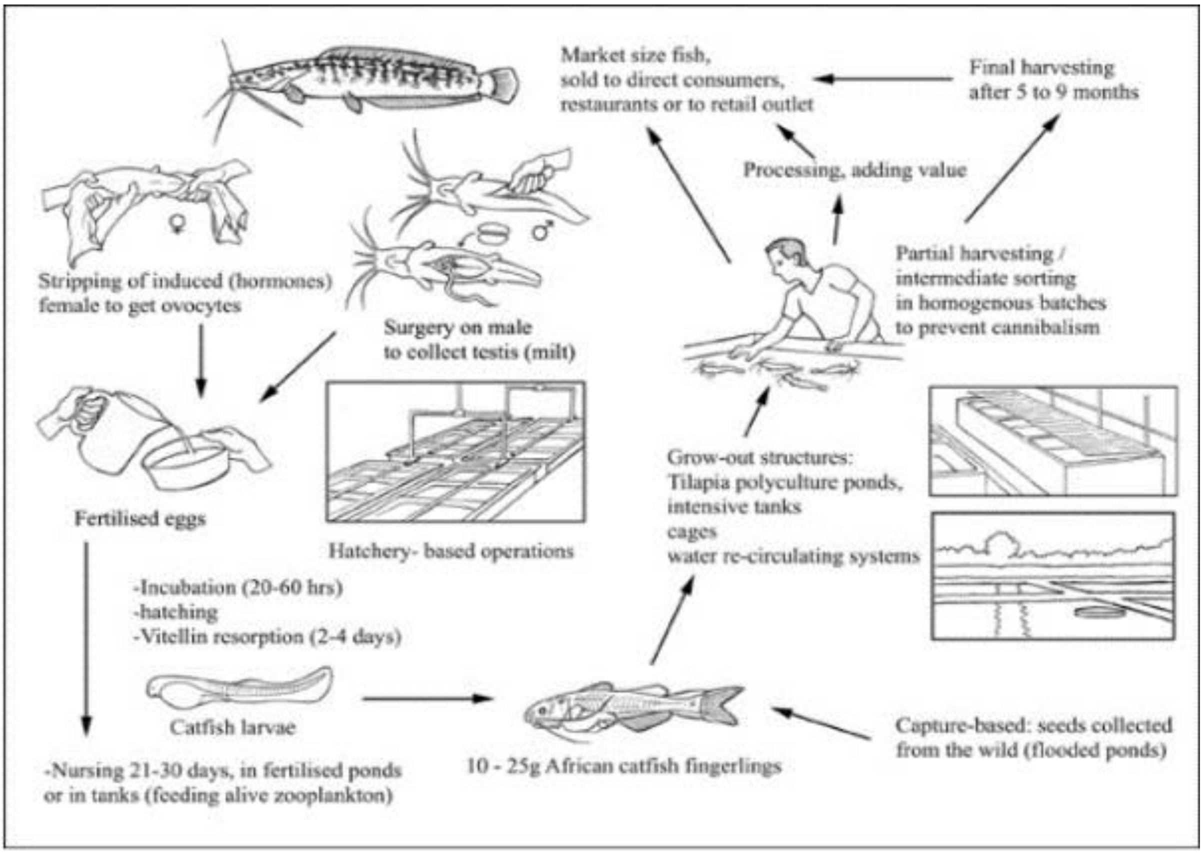


Figure 2-1: Production Cycle of the Sharptooth Catfish

Adapted from FAO 2010-2017.

Gonadal maturation starts in winter and the final gonadal maturation is associated with rising water levels and temperatures. Under stable environmental conditions, adult sharptooth catfish have mature gonads year-round. Under ideal conditions, a ripe female may lay about 60 000 eggs/kg. There is often a massive aggregation before spawning, during which the males fight among themselves for the right to court a female. The courtship rituals are fairly complex and involves the male fish twisting around the female in a U-shape like manner. Fertilisation of the eggs takes places externally. The sperm are motile for 80 to 120 seconds, which is a very short period compared with the sperm motility duration of tilapia, which is about 10 to 20 minutes (Hecht, et al., 1988).

Once the mating rituals have been completed, the female swishes her tail vigorously to mix the eggs and sperm and distribute the fertilized eggs. The adhesive eggs stick to submerged vegetation and hatch in 20–60 hours, depending on the incubation temperature. Rapidly hatching larvae begin to swim 35 hours after fertilisation and feed externally after 80 hours. Larvae feed and grow rapidly in the warm (usually >24 °C) nutrient rich floodplains, reaching 3-7 grams within 30 days. The larvae change to juveniles (when the fin rays begin to appear) after about seven days. The larvae and juveniles are secretive and seek out dark, confined microhabitats, where they feed on small invertebrates in shallow inshore areas. As flooded marginal areas dry up with the end of the rains, juveniles and adults make their way back to deeper water. There are usually two reproductive peaks during the year, in areas with two rainy seasons, corresponding in intensity to the magnitude of the rains.

In South Africa, spawning in the wild takes place at water temperatures above 18°C, however temperatures above 22°C are more common. Spawning usually occurs at night (as they are less vulnerable to visually-orientating predators during the night), after heavy rainfall, in recently inundated marginal areas of lakes or rivers. There is no maternal care of the young in the sharptooth catfish, except for the careful choice of a suitable spawning site. The shallow, recently flooded areas usually chosen for spawning are typically free of predators and rich in food resources.

In extensive hatcheries, larvae are fed with a mixture of animal products (egg yolks, offal etc.), just after vitelline resorption, for 4-6 days before being stocked at 50-80/m^2 in nursery ponds (FAO,2010-2017). The nursery ponds (where applicable) are usually fertilised beforehand (usually with chicken manure), to enhance zooplankton development. Small-scale farmers stock the post-larvae obtained from these procedures in ponds protected from predators by fencing. Post-larvae are fed with single ingredients or compounded feed. Harvesting is carried out after 21-30 days and fingerlings are graded; the average weight at this stage is 5-7 grams. The recommended size at transfer to production ponds should be >10 grams. Therefore, additional pre-fattening may be carried out, except when the volume of immediate demand drives hatchery operators to sell the fingerlings at 6 grams. Survival in a properly managed nursery system usually averages 25-35%.

In well-managed ponds, over 20 000 fingerlings with an average weight of 5 grams, can be produced per kilogram of female brooder. In the recirculation aquaculture systems, fry (0.05-0.1 grams) are fed with *Artemia* and 0.25 mm fry feed for 14 days, in 100-1 000 litre tanks (600 g/m^3 stocking density). Then, advanced fry (0.1-1.0 grams), stocked at 10 000/m^3, are fed 0.3-0.8 mm dry feed for 26 days in 600 -1 000 litre tanks. Juveniles (1-8 grams) are reared in 600-6 000 litre tanks at 400/m^3 for 20 days and fed 0.8-1.5 mm dry feed. Water temperature is maintained at 28 °C, and biofilters ensure that NH_3 and NO_2 levels remain below 3 and 1 mg/litre respectively. To avoid disease problems, all components of the system are disinfected between each cycle (FAO,2010-2017).

2.3. Physical requirements for the African Sharptooth Catfish

The physical requirements for the Sharptooth catfish discuss the feeding patterns and requirements, and water conditions that affect the production of catfish such as water temperature, salinity, water pH, and oxygen requirements. The physical requirements discussed below were used to inform the production assumptions for the generic economic model.

2.3.1. Feeding

According to Bruton (1979), the sharptooth catfish is omnivorous in nature. It displays both scavenging and predatory behaviour, with approximately 70% of feeding activity takes place at night. The fish is known to have extremely varied diets, ranging from consuming all types of aquatic invertebrates, small vertebrates, small mammals and plankton to fruits and seeds (Bruton,1979; Skeleton,2001). The high levels of amylase, protease, and gastric lysozymes, with wide temperature profiles which they possess, facilitate this opportunistic feeding habits and their ability to efficiently utilise a wide range of nutrients (Hecht, et al, 1988).

Feeding with a formulated feed is a prerequisite under culture conditions, where natural food does not have to be taken into consideration. The optimal diet should have a high protein content and the correct amino acid balance. Under ideal conditions, optimal growth rates and food conversions are achieved with diets containing between 35-42% crude protein (DAFF & WRC,2010). However, it is sometimes difficult to give a standard formulation for a balanced diet for the sharptooth catfish, as the composition of the formulated diets depends on the availability and prices of locally available feedstuffs.

In most African countries, over 90% of feed used by farmers is farm-made, and is either moist or dry feed (Hecht,2007; Ponzoni & Nguyen,2008). Moist ingredients that are commonly used for catfish feed in Africa and Asia include chicken entrails, minced poultry farm mortalities, abattoir waste, butchery sweepings, fish market waste (mainly fish entrails), maggots, termites, earthworms, trash fish, hotel or restaurant kitchen waste and live juvenile tilapia. In most instances, these moist ingredients are mixed with milled oilseed cakes (soy, cotton, sunflower, palm kernel) and relatively inexpensive ingredients such as maize, wheat or rice bran and dried brewery waste. Farmers also use moist ingredients such as chicken offal as a stand-alone feed and claim to achieve Feed Conversion ratios (FCRs) of around 1.3:1 (Ayinla,2007). Recent trials in Uganda have found that the use of chicken offal results in unacceptably high abdominal fat deposition (Matsiko & Mwanj,2008). However, it should be noted that fish with low abdominal fat content are least preferred in many other regions in Africa.

2.3.2. Salinity

Salinity is an important factor that affects the survival of different aquatic species, including the sharptooth catfish. Salinity concentration interacts with water temperature, dissolved oxygen, and other environmental factors. As such, it is known to influence growth, survival, and production potentials of fish, by its effect on osmoregulatory and metabolic activities (Gabriel, et al ,2012). Thus, unfavourable salinity concentrations can result into stress or even death of fish, depending on the species. For the culturing of sharptooth catfish, the optimum salinity range for larval rearing is between 0 to 2.5 ppt and a short-term exposure to higher salinities (2.5–7.5 ppt) could be effective in the treatment of ectoparasitic diseases (Hecht, et al ,1988). It is recommended that hatchery rearing of the sharptooth catfish occurs at the optimum low salinities of 4 – 6 ppt rather than in full fresh water, for at least 21 days (Britz & Hecht,1989 and Kawamura, et al,2017).

2.3.3. Water temperature

Although the sharptooth catfish is hardy and able to survive in most climate, temperatures below the optimal survival range can slow down their metabolism and food consumption. As such, the optimal temperature for culturing the fish is between 28 -30˚C (Jauro & Usman, 2015; Omenwa, et al., 2015) However, they can live in very turbid water and can tolerate temperature range of between 8 - 35 ˚C (Jauro & Usman, 2015; Hecht, et al., 1988) Furthermore, the required water temperature range for egg hatching is between 17 and 32˚C, (Hecht, 2007).

2.3.4. Oxygen Requirement

Oxygen is one of the principal limiting factors in aquatic respiration and metabolic reactions. In fact, it is an important water quality constituent that may impede production under aquaculture conditions. Low dissolved oxygen (DO) concentrations in an aquaculture system could indicate excessive richness of nutrients and biological overloading.

In addition, the amount of oxygen contained in water varies with temperature and salinity in a predictable manner. For instance, less oxygen can be held in fully air-saturated warm sea water than fully air-saturated cold freshwater. In the same manner, the oxygen requirement for culturing the sharptooth catfish depends on the water temperature and the feeding level. It is recommended that for optimum growth, the oxygen level for culturing the sharptooth catfish should not fall below 3 ppm but preferably, it should be 5mg/L or more (Hecht, et al., 1988).

2.3.5. pH Requirement

The optimum pH range that supports optimum growth rate in the sharptooth catfish is between a range of 6.5 – 8.0 (Jauro & Usman, 2015; Omenwa, et al., 2015).However, if the water becomes more acidic than pH of 6.5 or more alkaline than of pH 9.0 for long periods, reproduction and growth will diminish (Ivoke, et al., 2007).

2.3.6. Ammonia Requirement

Although the ammonia threshold concentrations for physiological disturbances, feed intake and growth are difficult to determine (Schram, et al., 2010), the Sharptooth catfish is known to have a high tolerance for ammonia toxicity (Hecht, et al., 1988; Ip, et al., 2004), and will usually tolerate up to 2.3 mg/L of ammonia concertation (Hecht, et al., 1988). Several defence mechanisms such as: active excretion of ammonium cation (NH^{+}_{4}), reduced ammonia production by reduction of proteolysis and/or reduced amino acid catabolism and a high ammonia tolerance of tissues and cells, allow this fish to cope with increased internal ammonia. As such, it is unclear whether culturing of the sharptooth catfish at high water ammonia concentrations will result in any physiological disturbances, reduced feed intake and growth, or, impinge on the welfare of the fish.

Under normal hatchery rearing conditions, ammonia does not appear to be a limiting or lethal factor. Furthermore, the cleaning of larval appear unnecessary as uneaten food and faeces do not to adversely affect water quality to an extent that is detrimental to the larvae. According to Ajiboye & Aremu (2015), ammonia concentration becomes toxic to the fish only when there is reduction in the level of dissolved oxygen. Apart from ammonia, the nitrite (NO_2) concentration should also be monitored. Nitrite Concentration should be less than 10 times that of chlorides in water. For example, if the Nitrite level is 0.5 mg/L, chlorides should be at least 5 mg/L.

3. Potential Culture Systems

The potential production systems identified are considered in the generic economic model to determine the financial feasibility of each system from an economic perspective. Each production system is unique in terms of the infrastructure requirements and operational costs associated with the system. The potential culture systems that could be used to culture African Catfish in South Africa include the following:

3.1. Recirculating Aquaculture System (RAS)

RAS is typically an intensive system that allows farmers to control environmental conditions year-round. Although the construction of this system requires a higher start-up cost than that of either pond or cage culture, if designed and managed properly, fish can be produced all year round, thereby making the economic returns worth the increased investment. The use of RAS can reduce the use of fresh water to a minimum and has been proven to be a feasible method to produce the sharptooth catfish, both locally and internationally. However, farm management and farming practices are important to maximise the economic efficiency of culturing catfish under the RAS. Good farm management practices should include the following:

I. A well-balanced stocking plan,
II. An adequate feeding plan,
III. Capability to monitor physical and chemical water quality variables,
IV. Capability for counter measures, and
V. An adequate maintenance plans.

Although the design elements of recirculation systems vary widely, the main components of recirculation systems consist of:

I. Fish rearing tanks,
II. Solids removal device (sump),
III. Water circulation pump.
IV. Water heating system (where applicable),
V. Aerator or oxygen generator,
VI. Protein skimmer,
VII. The fish rearing tanks,
VIII. The mechanical and biological filter, and
IX. Water testing kits (FAO,2017).

Some systems apply additional treatment processes such as ozonisation, denitrification, and foam fractionation. The fish rearing tanks are generally circular to facilitate solids removal, although octagonal tanks and square tanks with rounded corners provide a suitable alternative with better space utilization. Drum filters are widely employed for solids removal, although other devices (bead filters, tube settlers) are often used. In oxygenated systems, a stage is provided for vigorous aeration to vent carbon dioxide into the environment.

Rearing tank retention times are relatively short (e.g. one hour) to remove waste metabolites for treatment and return high quality water. Most recirculation systems are designed to replace 5 to

10% of the system volume each day, with new water. This amount of exchange prevents the build-up of nitrates and soluble organic matter that would eventually cause problems (FAO,2005-2017).

The commercially applied stocking density for the sharptooth catfish in a RAS system is 200 – 500 kg/m^3 (Nieuwegiessen, et al, 2008). Furthermore, fry (0.05-0.1 grams) are usually reared and fed for a period of about 14 days at a stocking density of 600 g/m^3 (FAO,2010-2017). Advanced fry (0.1-1.0 grams), are stocked at a density of 10 000/m^3, for about 26 days. Also, juvenile catfish (1-8 grams) are reared at a stocking density of 400/m^3 for 20 days (FAO,2010-2017). To avoid disease problems, all components of the system are disinfected between each cycle.

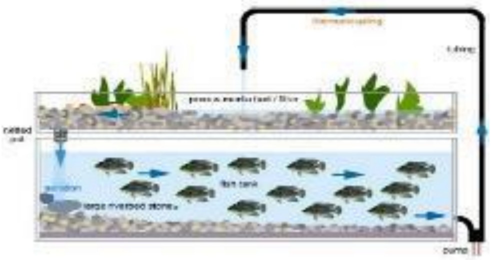
<u>Advantages of using the recirculating aquaculture systems</u>

I. The RAS is advantageous over other aquaculture systems in the reduction of incoming water volume,
II. Reuse more water within the culture system,
III. Reduction in the amount of water released and the effluent quality,
IV. Higher level of biosecurity and lower risks from external contaminants,
V. The system allows for intensive aquaculture production to be undertaken on a smaller footprint,
VI. The system can also be located closer to markets and infrastructure, such as highway connections and utilities,
VII. Indoor operations protect the fish stock from seasonal variations in temperature, allowing year-round production that satisfies constant market demand,
VIII. Relatively small area is needed,
IX. Suitable for a wide range of climatic conditions, and
X. Security is easy to manage.

<u>Disadvantages of using the recirculating aquaculture systems</u>

I. High capital investment required to establish system,
II. Technology driven system – not always user friendly,
III. There are many different bio filtration systems involved in operating the systems. These would need to be screened with the best adapted to local conditions,
IV. High and constant demand of power,
V. Highly technical installation, and
VI. Maintenance is relatively high.

3.2. Aquaponics



Aquaponics is an aquaculture production system that mutually integrates fish farming with soil less crop production (mostly vegetables) in one recirculating system (Somerville, et al,2014). As such, the aquaponic system provides insight into increasing the efficiency of food production while taking cognisance of the principles of sustainable agriculture.

Aquaponic systems require very little water and land for the intensive production of sharptooth catfish, hydroponic vegetables, and other crops such as culinary herbs, medicinal herbs and cut flowers. The aquaculture effluent typically supplies most of the required plant nutrients in adequate amounts, with only little supplementation required (Rakocy, et al, 2004). As the aquaculture effluent flows through the hydroponic component of the recirculating system, fish waste metabolites are removed by nitrification and direct uptake by the plants, thereby treating the water, which flows back to the fish-rearing component for reuse. Continuous generation of nutrients from fish waste prevents nutrient depletion while uptake of nutrients by the plants prevents nutrient accumulation, extends water use, and reduces discharge to the environment. Culture water can be used continuously for years, under the aquaponics system.

The technology associated with aquaponics is fairly complex, if any one part of the system fails, the entire system can collapse (Somerville, et al,2014). Aquaponic systems can be highly successful, but they require careful management, as they have special considerations. The main factors when deciding where to place an aquaponics unit are: stability of ground; access to sunlight and shading (most of the common plants for aquaponics grow well in full sun conditions, however, extreme environmental conditions can stress plants and destroy structures); exposure to wind and rain (strong and prevailing wind and rain fall can cause damages); availability of utilities; and availability of a greenhouse or shading structure (FAO,2014). The essential components of the aquaponics system include the following:

I. The fish rearing tanks,
II. The mechanical and biological filter,
III. The plant growing units (media beds, Nutrient film technique (NFT) pipes or Deep-water culture (DWC) canals),
IV. Water/air pumps,
V. Sump tank, and
VI. Water testing kits (FAO,2017).

The fact that sharptooth catfish are air breathers makes them ideal for the aquaponic system, as a sudden and dramatic drop in dissolved oxygen which can occur in aquaponic systems would not result in drastic fish mortalities when compared with other freshwater species such as tilapia. Also, given the high tolerance to low dissolved oxygen levels and high ammonia levels, catfish can be stocked at higher densities, provided there is adequate mechanical filtration. Regarding waste management, it is worth noting that suspended solid waste produced by catfish is less voluminous and more dissolved than that of tilapia, thus, facilitating greater mineralisation within the system.

Advantages of using the aquaponic system to produce sharptooth catfish

I. It is a labour-saving technique, and can be inclusive of many gender and age categories,
II. The system allows for sustainable and intensive food production,
III. Two agricultural products (fish and vegetables) are produced from one nitrogen source,
IV. It is extremely water-efficient and creates little waste,
V. Aquaponic systems don’t require large areas of land or space to be implemented,
VI. Does not use fertilizers or chemical pesticides,
VII. Higher level of biosecurity and lower risks from outer contaminants, and
VIII. Higher control on production leading to lower losses.

Disadvantages of using the aquaponic system to produce sharptooth catfish

I. Expensive initial start-up costs compared with soil production or hydroponics,
II. Requires extensive technical expertise and experience,

III. Fish and plant requirements do not always match perfectly; For example, fish growth may be affected negatively, as water gets cooled down when passed through plant growing media. Plants may also suffer excessive heat and humidity from water coming from the aquaculture media,
IV. Not recommended in places where cultured fish and plants cannot meet their optimal temperature ranges,
V. Limited system management choices compared with stand-alone aquaculture or hydroponic systems (no pesticides for the plants, no antibiotics for the fish),
VI. Daily management is mandatory, this increases the operational cost, and
VII. Energy demanding; requires reliable access to electricity, fish fingerlings and plant seeds.

3.3. Cage culture

Cage culture is an aquaculture production system where fish are held in floating net pens. The system utilises existing water bodies but encloses the fish in a cage or basket on all sides (including the bottom), while permitting water exchange and waste removal into the surrounding water (Masser, 2008). Cages are constructed in a variety of shapes using materials such as bamboo or wooden slats and wire, nylon and/or alternative synthetic meshes. Support structures are used to hold cages on the water surface or to suspend it above the bottom of a body of water (Beveridge,1984). Cage culturing makes it possible to grow fish in different water bodies (lakes, large reservoirs, and rivers) where draining and seining would be difficult or impossible. They are also a good alternative for estuaries and coastal bays. The use of cages in an existing water body whether community or government owned, enhances aquaculture, and enables rural and small-scale farmers to go into aquaculture for increased productivity in domestic fish production. The system is also particularly suited to the rural poor who do not have access to land for any other form of agricultural production.

In terms of the sharptooth catfish production in cages, stocking density, which is related to the volume of water or surface area per fish is an important factor. Too high stocking density may result in increasing stress, which leads to higher energy requirements, causing a reduction in growth rate and food utilization. Contrarily, in the case of low stocking densities, fish may not form shoals and feel uncomfortable. Consequently, identifying the optimum stocking density for a species is a critical factor, not only for designing an efficient culture system, but also for optimum husbandry practices. Controlling fish size and production are the two important tasks to meet the market demand, as price of fish is determined by the market demand of supply (size and production), and that in turn depends on their growth. The important components of a cage culture system are:

I. Frame (this can be constructed from wood, iron, steel, etc.),
II. Floating device,
III. Mesh or netting,
IV. Cage cover (to prevent fish losses from jumping or predation), and
V. Feeding ring (to retain floating feed and prevent wastage).

The selection of an appropriate site forms the most critical aspect of the cage culture system, as it will help to minimise most of the risks associated with operating the system. Lakes, reservoirs, ponds, rivers, and streams can be used as potential sites, provided that the water quality and carrying capacity is suitable and there is adequate water depth beneath the cages to allow water movement. Furthermore, the cage units should be designed to withstand prevailing wind and wave conditions at the selected site. Good water exchange is also important in cage culture to replenish oxygen and flush away wastes.

The **advantages** of culturing the sharptooth catfish is the cage culture system include the following:

I. Ease of installation,
II. Flexibility of management,
III. Effective use of fish feeds,
IV. Low labour requirements,
V. Better control of fish population,
VI. The mobility and flexibility of the system allows it to be removed from one place to another, in case of emergencies,
VII. It requires less investment, because it uses existing water bodies, simple technology, and swift return of investment,
VIII. It allows for simple close observation and sampling of fish; therefore, only minimum supervision is needed, and
IX. Fish handling and harvesting are very simple and helps to maintain the non-seasonal supply of the fish.

Disadvantages of the cage culture system

I. Feed must be nutritionally complete and kept fresh,
II. External water problems can impact on fish (oxygen levels, pH levels, water quality etc),
III. Diseases are a common problem in cage culture. The crowding in cages promotes stress and allows disease organisms spread rapidly. Also, wild fish around the cage can transmit diseases to the caged fish,
IV. Caged fish are unable to access natural food sources,
V. A high food loss is recorded with cage culture as feed is lost through the cage mesh/materials into the water,
VI. The high fish density with the high feeding rates, often reduces dissolved oxygen and increases ammonia concentration in and around the cage, especially if there is no water movement through the cage, and
VII. It is difficult to control aspects such as water temperature and quality specifically if using natural water bodies such as dams, lakes, or rivers.

3.4. Raceway Systems

Raceways for fish culture are series of tanks (rearing units) which are relatively shallow and continuously supplied with high-water flow (usually along the long axis), to sustain aquatic life. A typical raceway culture system consists of a long and narrow canal of concrete with a water inlet and outlet to maintain a continuous flow of fresh water. With fresh water continuously flowing through the canal, the water quality is always high, and fish can be cultured at high densities. Furthermore, in an ideal raceway system, the water flow is at an almost uniform velocity across the tank cross section. However, friction losses at the tank-water and air-water boundary layers causes water velocities to vary across the width and depth of the raceway. The greatest water velocities are found at mid-depth, with slightly reduced velocities at the air-water interface and greatly reduced velocities along the raceway bottom, towards the outlet.

Circular rearing units are more thoroughly mixed and provide relatively uniform environmental conditions throughout the tank. The basic structure of raceway systems should be designed in a way that none of the parts of culture waters are stagnant in the tanks, otherwise debris or faeces would be accumulated in locations, thereby deteriorating water quality, or causing outbreaks of disease in the system. As such, the primary factor to be considered in raceway construction is the available water sources. When the available water sources are sufficient to support the entire system, the raceways can be located across the water current. However, in cases where the water sources are a limiting factor to the system, the raceways should be located adjacent to a water source with a current. While raceway systems ensure the water is well oxygenated and flowing, the fish may be vulnerable to external water quality and changing conditions, as the ambient water temperatures significantly influence growth rates. In order to counteract this, the generic economic model assumed the raceways would function in a similar manner to the RAS, and incorporated tunnel infrastructure into the capital expenditure required.

The number of raceways in a series varies with the pH level, with the slope of the land also playing an important role with regards to aeration (a 40 cm drop between each raceway is recommended). To maintain good hygiene, water quality and control disease problems, the parallel design raceways is the most suitable, as any contamination flows through only a small part of the system. Ground water can be used where pumping is not required, and aeration may be necessary in some cases. Supersaturated well water with dissolved nitrogen can cause gas bubbles to form in the blood of fish, preventing circulation, a condition known as gas-bubble disease. Alternatively, river water can be used; however, temperature and flow fluctuations may alter production capacity.

<u>Advantages of using the raceway system</u>

I. Stocking densities for raceways are usually higher than for other culture systems,
II. The labour costs associated with cleaning, grading, moving, and harvesting is significantly lower in raceway systems,
III. Raceways offer a much greater ability to observe the fish. This can make feeding more efficient,
IV. Disease problems are easier to detect and at earlier stages in raceway systems. Furthermore, disease treatments in raceways are easier to apply and require fewer chemicals than a similar number of fish in a pond (due to the higher density in the raceway),
V. Raceways also allow closer monitoring of growth and mortality, and therefore allow for better inventory estimates compared to ponds, and
VI. Management inputs such as size grading are much more practicable in raceways compared to other culture systems such as ponds; harvesting is also easier in this system.

<u>Disadvantages of using the raceway system</u>

I. The required hydrological conditions for the construction of raceways limit the number of sites where a farm could be constructed
II. The risk of theft of the stock is also higher with this system,
III. Increase risk of disease outbreaks with the high stocking density of catfish,

IV. Most raceway systems rely on commercial feed; hence the maturity of the species is greatly influenced by the level of protein and other nutrients supplied to the fish,

V. The need for large constant flows of consistent, high-quality water can pose a challenge in water scarce areas or during the drought period,

VI. Locating and securing a proper water supply is a major consideration,

VII. Commercial viability often requires that the water gravity flows through a series of raceways before it is released. This adds a requirement for an elevation of the water source and suitable topography for the gravity flow between raceways,

VIII. The release of large volumes of effluent with low retention times is another major limitation for raceways,

IX. Raceway aquaculture is generally high-tech and high risk, as problems can develop rapidly if the system fails, and

X. The system requires a constant energy supply, which in turn has an impact on the operational costs with electricity costs being a key factor for producers to account for.

3.5. Flow-Through Systems

In the flow-through systems, water flows in and out continuously. As such, the systems require adequate supply of good quality water, which in turn allows for higher stocking densities. Unlike the recirculating aquaculture system that filters and re-cycles water for re-use, the flow through system discards its water after use. Hence, the system relies heavily on constant or periodic water exchange, to flush out fish waste products.

Exchange rates are determined by the available water quality and quantity, the fish biomass, and feeding rates. As a rule of thumb, the volume of water needed for a facility is the amount required to replace 100 percent of the tank water every 90 to 120 minutes (DeLong, et al, 2009).Water for flow-through facilities is usually diverted from streams, springs, or artesian wells, to flow through the farm by gravity. Flow-through systems would be ideal for culturing the sharptooth catfish in cooler regions of the country, as they are able to tolerate a wider range of temperature (between 8 - 35 ˚C).

Using surface water for flow through systems is not advisable, although there may be exceptions. The quantity of surface water available may vary during a drought season. The water quality may also vary because of rainfall runoff, agricultural activity, or other development activity in the watershed area. Even though groundwater is considered a better source, it is important to gather information with regard to water quality of a site before developing the culture operation. For example, water tapped from shallow wells may contain organic matter and unacceptable levels of ammonia or hydrogen sulphide gas. Geothermal water sources may have high levels of dissolved minerals that affect fish health. It might be possible to treat groundwater before using it, though the operator would need to determine whether or not treatment is economically feasible (DeLong, et al ,2009).

<u>Advantages of using the flow through system</u>

I. This aquaculture system can be operated with reduced levels of investment because the transportation of oxygen and waste will be done by the current of the water body.
II. The fish grows in its natural habitat.

Disadvantages of using the flow through system

I. The success of operating a flow-through system depends on natural conditions and environmental events. For example, a cold winter or a hot summer can limit the production,
II. The system can get easily polluted or contaminated. For example, water run-off from nearby farms where pesticides have been used can easily pollute the water bodies,
III. The diluted waste from the system can also have an inadvertent influence of the downstream habitat,
IV. Water discharged from the flow-through tank systems may pollute receiving waters with nutrients and organic matters,
V. The discharge of effluent water may require a permit, with required periodic testing and oversight, and
VI. The culture of sharptooth catfish in a flow through system can have higher labour and energy costs for pumping water, than pond culture methods.

3.6. Pond Culture

The pond culture is the most versatile culture system for extensive, semi-intensive, and intensive catfish production. However, the pond culture is only economically viable in areas with a warm year round climate, suitable land and relatively large quantities of water (Normal-Lopez & Bjorndal, 2010) The ideal size of production ponds for sharptooth catfish is between 1 000 and 2 000 m^2 (Hecht, et al ,1988).

The optimal slope to build such ponds is 1:20 m. Ideally, all ponds should receive water by gravity feed. Similarly, the discharge should also be under gravity. This circumvents the necessity of utilizing expensive pumping equipment. If water is to be pumped, it must obviously be cost effective. It is also important to consider the past usage of the land, as residues of toxic chemicals (particularly pesticides and herbicides) may still be present in the soil.

In monoculture production systems the recommended stocking density of 10 fingerlings/m^2 is recommended (Hecht et al., 1988). However, it is important to thin out the population at regular intervals, to maintain a maximum standing crop of 40,000 kg/ha with a constant daily water exchange rate of 25%. This is very important at these high standing crops, because waste accumulation (uneaten feed, excreta, etc.) will stress the fish and may trigger disease outbreak.

Primary considerations when selecting a suitable site for pond construction include: climate (temperature must be within the optimum range, for at least eight months of the year), topography, adequate water quality and quantity, soil type, feed sources, proximity to technical services and proximity to suitable market. Other important factors include the regulations laid down by provincial nature conservancies, town and regional planning departments, the South African Bureau of Standards, and agricultural water rights.

Three types of ponds are required for a successful catfish farming. Although the method of their construction is similar, they vary in depth and outer dimensions. The pond design, shape and dimensions varies depending on the size of land available, producer preference and site-specific considerations. While design has little bearing on the production process, catfish producers must ensure they have adequate water supply to meet the water requirements based on the tonnage of catfish being produced. The three types of pond include:

I. **The broodstock pond**: This pond should not exceed one metre in depth, in order for the temperature of the water in the ponds to rise as rapidly as possible during early spring. The size should also be between 100 and 500 m^2. Depending on the scale of operation, there should be an adequate number of these ponds, to allow for the separation of broodstock obtained from different areas and for genetic selection.
II. **The fingerling pond**: To allow for easy management, the fingerling pond should be between a quarter and half the size of the grow-out ponds (i.e. approximately 250 to 500 m^2). Ideally there should be one fingerling pond for every four or five grow-out ponds. The generic economic model accounts for RAS tanks for the 10-100-gram fish rather than fingerling ponds. These can be considered nurseries to ensure the catfish are large enough to cope in the larger grow-out ponds.
III. **The grow-out pond:** The grow-out pond should be between one tenth and one fifth of a hectare in surface area (i.e. 1 000 to 2 000 m^2), not more than 1,5 metres deep at the deep end and one metre at the shallow end. larger or smaller ponds can also be constructed, depending on the topography of the site.

<u>**Advantages of using the pond culture system**</u>

I. Can be a low-tech method of culturing the sharptooth catfish,
II. May be more forgiving (in terms of the different production parameters that needs to be met) when compared to other more intensively stocked production systems,
III. Pond culture works well with other farm crop or livestock operations,
IV. The pond culture system is not labour intensive, hence operational cost is reduced when compared to other culture systems, and
V. Non-productive farm land with suitable water supply, climate, topography, etc. may be converted to earthen or constructed grow-out ponds.

<u>**Disadvantages of using the pond culture system**</u>

I. It is difficult to keep track of fish inventories within a pond culture system,
II. Ponds may be subject to predators and pathogens,
III. Producers using the pond system sometimes need to compensate for weather events, temperature, water quality and algal blooms, while managing the fish,
I. There is a greater risk of disease outbreak in pond systems, and
II. Ponds take longer to prepare (excavate) and fill with water.

3.7. Culture System Summary

Having presented the advantages and disadvantages of various culture systems for African Catfish production in South Africa based on local and international literature, Table 3-1 below provides a summary for each production system. This table gives an indication of whether the system is viable or non-viable for African Catfish production in South Africa. Based on the system status, the generic economic model was developed to provide additional insight into the financial viability of the potential systems, which is discussed in the Financial Analysis.

Table 3-1: Catfish Production Systems Summary

System	System Overview	System Status
Pond Culture	I. Suited for commercial production – rural areas II. Minimum technological requirements III. Low operational costs (labour, electricity & water) IV. Relies solely on artificial feed V. Low stocking density due to water quality VI. Low control of water contamination, pollution, or wild species invasion	Viable
Cages	I. Can be viable II. Low operational and setup costs III. Can present several challenges for producers IV. Difficult to maintain water and production variables if using a natural water body (dam, river lake etc) V. Disease outbreak and spread is a major risk VI. Stocking densities are problematic with cage culture due to space and feed requirements	Viable
Aquaponic	I. Tested system II. Suited for commercial production – urban areas III. Can be used in areas not usually supportive of vegetable production IV. Controlled systems (temperature, biosecurity etc) V. Growth rates of fish can be increased in closed systems VI. Dual income stream (fish & vegetables) VII. Fish vs Plant combinations can be difficult to balance VIII. Energy requirements are higher than other systems IX. Requires less water & land than more extensive systems X. Requires constant monitoring and maintenance – labour intensive	Viable
RAS	I. Tested system II. High level of control & biosecurity monitoring III. Ideally suited for commercial production in urban areas IV. Low space & water requirements High operating costs V. Dependant on artificial and enhanced feed VI. High energy usage VII. Generally low mortality rates (dependant on management & skills)	Viable
Flow-through systems & Raceway Systems	I. Tested system II. Requires constant heating of water – not economically feasible III. Prone to drought & water shortages – specifically if water source is a surface water body IV. Water source can be affected by pollution or contaminants V. Permits required for waste water discharge	Viable
Ranching	N/A	N/A

4. Geographical distribution of the African Sharptooth Catfish in South Africa

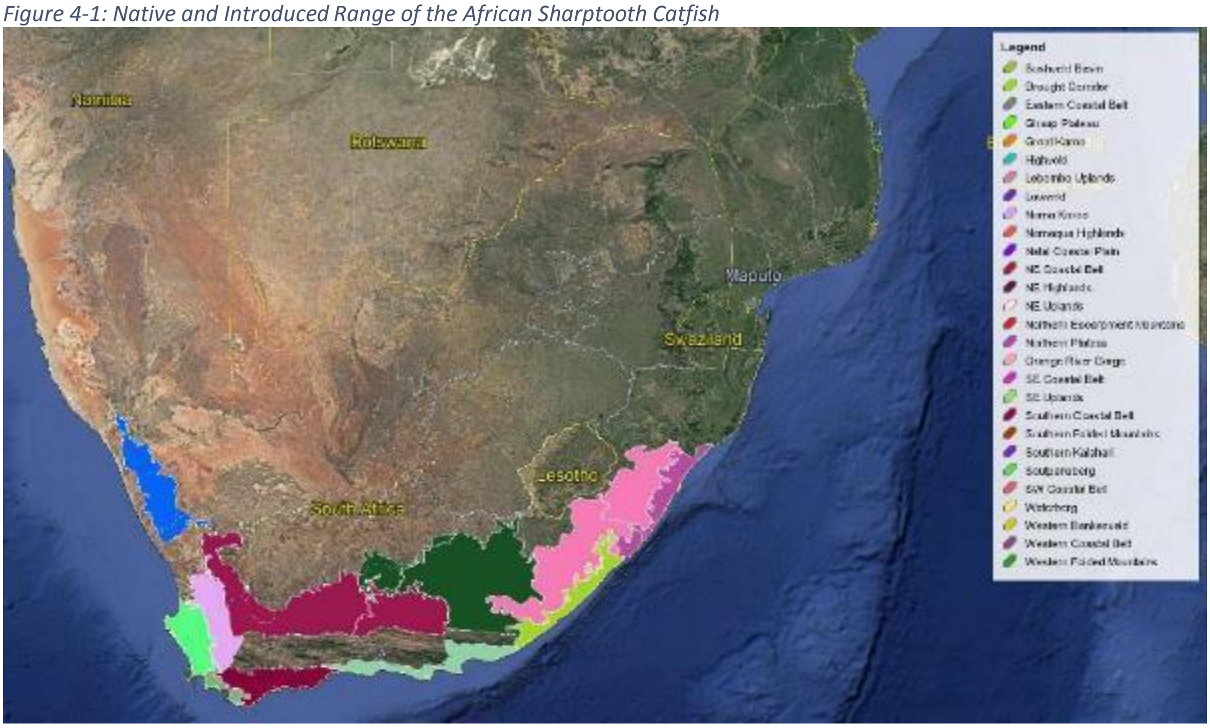
As the climatic and geographic conditions differ across South Africa, it is important to understand the suitability of the nine provinces for African sharptooth catfish production. Temperature is a key influencing factor for aquaculture as it determines and impacts on the type of production systems that can be used, as well as has financial implications relating to water heating and infrastructure costs, which can be seen in the generic economic model for catfish.

4.1. Suitability Assessment

The African sharptooth catfish may be cultured throughout most lowland areas of South Africa with the current technology used. However, the optimal temperature for culturing this species is between 28 -30°C. Hence, the most efficient areas for open culture systems (with little or no technology application) would be provinces which experience warm summers and relatively warm winters. As such, the main factor considered in determining the thermally suitable areas to culture sharptooth catfish in South Africa is the optimal temperature under which they survive. Other relevant factors such as water quality, water temperature, soil quality, topography, infrastructure, type of technology, skills availability, etc., should also be considered but at a site-specific level.

The figure below indicates the native and introduced regions for the African Sharptooth Catfish in South Africa.

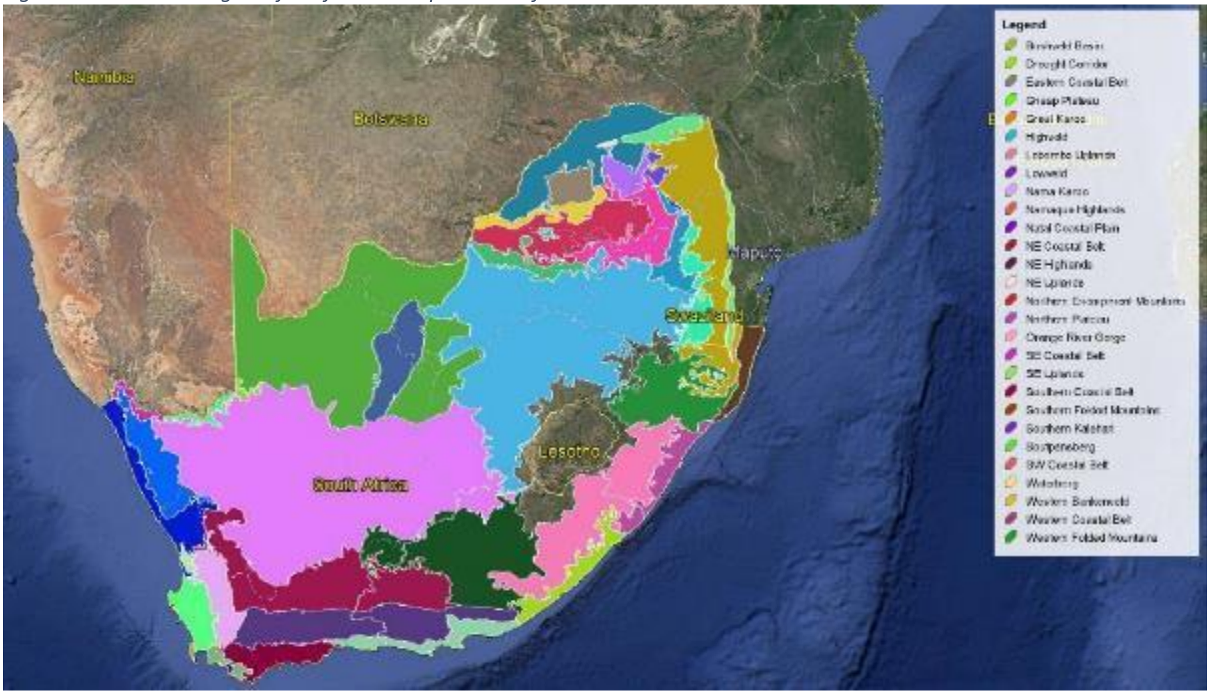
Figure 4-1: Native and Introduced Range of the African Sharptooth Catfish



(Urban-Econ,2018)

The image below identifies the suitable regions for the African Sharptooth Catfish based on the BRBA assessment conducted which identifies regions based on suitable air temperatures conditions that are suitable for catfish.

Figure 4-2: Suitable Regions for African Sharptooth Catfish



(Urban-Econ,2018)

Based on the map above, it can be seen that the African sharptooth catfish is expected to be able to survive across South Africa, with the exception of the Eastern Escarpment mountains due to low temperature ranges. It is crucial to understand that the figure above is based on air temperature conditions, and it should be noted that naturally occurring populations of catfish may be seasonal in regions that have cold winter temperatures, falling outside the optimal range for the African sharptooth catfish to survive. Aquaculture operations, provided they have heating equipment, water temperature regulation measures and well-designed systems can produce catfish year-round, however during winter months high operational expenses should be expected as well as slower than normal growth rate.

Care should be taken by aquaculture operations, as should catfish escape from production systems, they may be able to survive and establish natural populations in warm conditions. Provinces that experience warm to moderate temperatures year-round that may offer optimal production conditions with lower heating requirements include the northern regions of the Kwa-Zulu Natal coast line, Limpopo, select regions of Mpumalanga and select regions of the Eastern Cape.

4.2. Key Location and Site Requirements

There are many factors that can influence the success of an aquaculture enterprise. Site selection is one of the most important factors but often does not get adequate attention. Important factors that have to be considered in selecting a specific site for culturing the African sharptooth catfish are:

I. Climate (water and environmental temperature),
II. Slope and topography (flood-prone areas should be avoided),
III. Soil type (applicable to open culture systems),
IV. Quantity and quality of water must be analysed (pH, alkalinity, ammonia, nitrite, etc.), and
V. Proximity to market (market research, demand, price, distance to processing plant, etc.).

4.3. Key requirements for profitability

In addition to the financial results obtained from the generic economic model, the following factors should be considered as they could impact on the profitability of an African Catfish operation:

I. Hatchery (induced spawning),
II. Fast growing strain,
III. Suitable freshwater temperature,
IV. High protein feeds,
V. Appropriate water quality and quantity,
VI. Suitable site with right soil type, slope, and topography,
VII. Economies of scale and consistent volume of production,
VIII. Access to market,
IX. Some value addition (where possible, to make products more attractive to consumers), and
X. Disease management and control.

5. African Sharptooth Catfish Market Analysis

'Catfish' is a generically used name for a diverse group of ray-finned fish species, of which the most common ones, in the Aquaculture sector, are:

- The 'African Catfish' (*Clarias gariepinus*) – indigenous to Africa but is also produced in Asia and Europe.
- The 'Channel Catfish' (*Ictalurus punctatus*) which is mostly farmed in the United States of America, and
- The 'Walking Catfish' (*Clariidae*) and 'Shark Catfish' (*Pangasiidae*) which are heavily culture in the Asian region

This market analysis however, will focus on the ***African sharptooth catfish*** industry, within the context of the overall catfish species trends of production, consumption, and trade. Specific market requirements of the African catfish and barriers to entry will also be discussed with regard to the local and regional sphere.

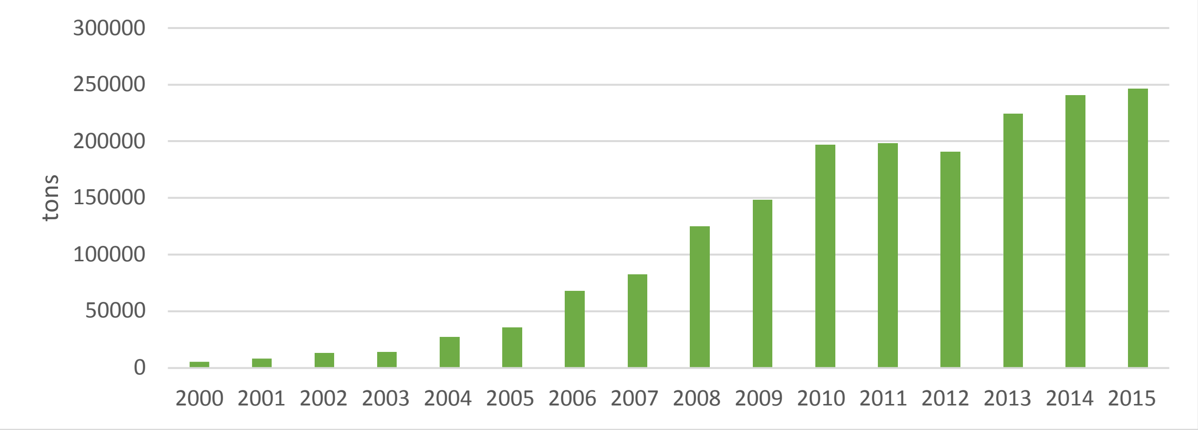
5.1. Production and consumption

The following section considers the global, regional, and local supply, demand and consumption trends and patterns for catfish.

5.1.1. Global, Regional and Local Supply Analysis

The African sharptooth catfish have been cultured for centuries within the traditional captured-based aquaculture system; however, it was only the mid 1970's that commercial trail was initiated. This was followed by research in both Europe (largely focused in Belgium and the Netherlands) and Africa (for example Central African Republic, South Africa, Côte d'Ivoire, and Nigeria, among others.), focusing specifically on improving the production of catfish (FAO, 2017). Global production of the African Catfish has picked up significantly since the mid-2000's, when production was set at about 5,400 tons, reaching a record of over 67,000 tons in 2006, followed by nearly 200,000 tons by 2010, and with top record of 246,477 tons in 2015 as seen in Figure 5-1 below .Based on the past growth rate and using linear projection, it is likely that the industry will continue expanding and reach close to 300,000 tons during 2017-2018.

Figure 5-1: African Catfish global production (1990-2015)

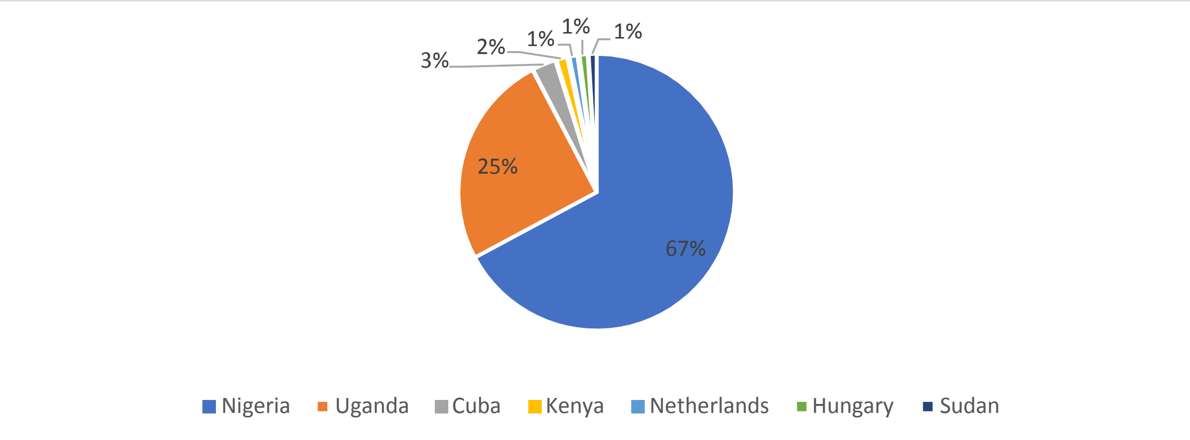


Source: FAO, 2016

The massive production growth in the global industry is attributed to the development of the farming technology and farming management capacity (FAO, 2017), and consumer behaviour (with preferences to healthy proteins products) (Banrie, 2012).

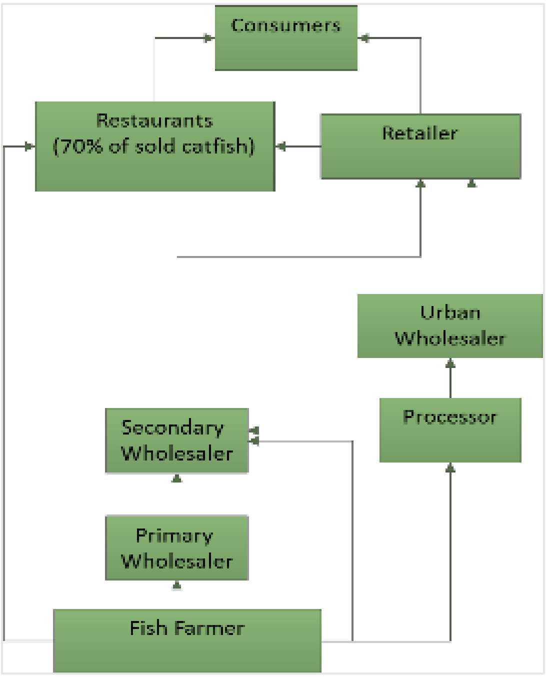
Nigeria is by far the largest global producer of farmed African catfish, with reporting figures of 160,000 tons produced during 2015, which accounts for roughly 65% of total global Catfish production (Figure 5-2) (FAO, 2016). Following Nigeria is Uganda with 24.3% (60,000 tons), Cuba with 2.8% (6,800 tons) and Kenya, Netherlands, Hungary, and Sudan (each with about 1% which is between 2500-3000 tons of global production). According to FAO (2017), Brazil, Syrian Arab Republic, Cameroon, and Mali are also producing significant quantities of African Catfish.

Figure 5-2: Global Production of Africa Catfish (2015)



Source: FAO, 2016

Figure 5-3:Nigerian domestic catfish industry value-chain

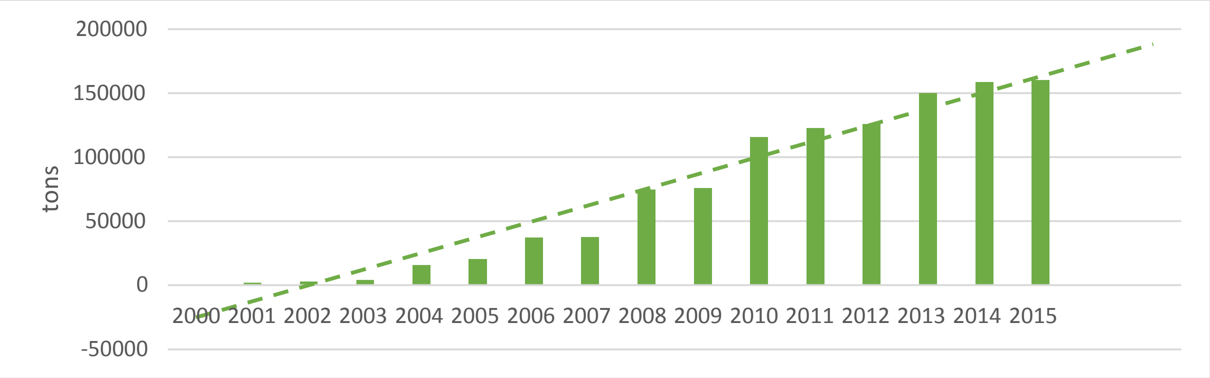


Nigeria's catfish industry has experienced fast growth during two periods: mid 2000's and at 2010 (Figure 5-2). This was followed by the global trend of Catfish farming expansion, which is likely due to improvement in farming technology and practice and due to increase in local demand driven by preferences such as health awareness (Banrie, 2012). To support such growth, the Nigerian's catfish industry value-chain had to be evolved. This included commercial large-scale farms which either engage with primary wholesalers or processing factories. Additional growing interactions were found between producers and local restaurants (Figure 5-3) (Gorman, 2009).

On the contrary, weakness of the industry includes: limited supply of fingerlings and formulated fish feed, as well as limited government interventions (to establish adequate infrastructure for hatcheries and fingerling production) and producer's associations/organisation that improve direct access to market (i.e.: local restaurants and the like) (Gorman, 2009; Banrie, 2012).

Projected figures indicate that catfish production in Nigeria may reach close to 200 000 tons in 2017/2018. This is based on current growth trends in the catfish industry, which can be seen in Figure 5-4 below.

Figure 5-4: Nigerian African Catfish Production (2000-2015)



Source: FAO, 2016

Despite the potential of catfish industry in Nigeria, the fish farming industry is still considered to be in its infant stage when compared to the larger domestic market potential and the size of Nigeria population of 186 million (The World Bank, 2017). Most of Nigeria's catfish production is situated in the Western regions of the country, while other catfish species such as the *Heteroclarias* are dominant in the South-Eastern parts of Nigeria (Banrie, 2012). Additional African countries that produce substantial amount of African Catfish are: Ghana, Cameron, and Mali as seen in Figure 5-5 below (FAO, 2017).

Figure 5-5: Major African Catfish producing Countries in Africa (2016)

Local production in Africa (e.g.: Nigeria, Uganda etc) is commonly done in extensive earth pond system and is mostly aimed at the local domestic markets. This is illustrated in Figure 5-6 below.

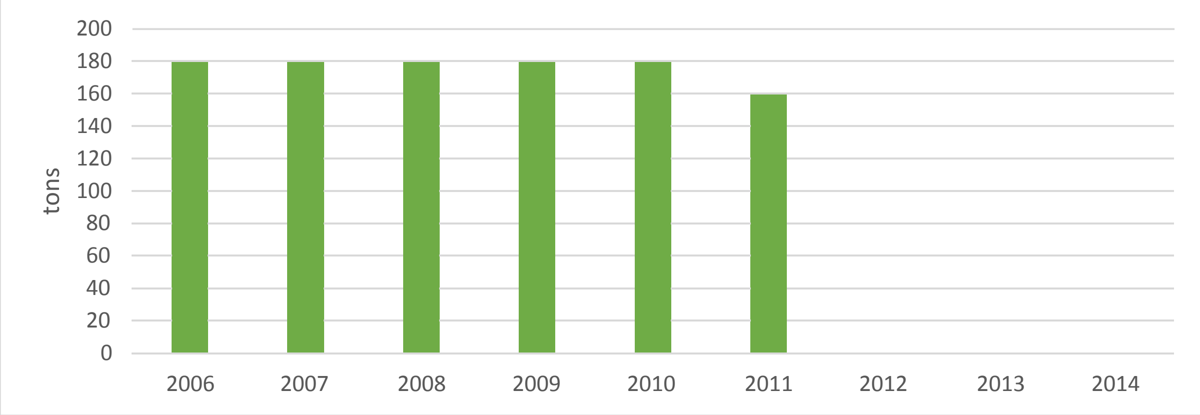
Figure 5-6: Extensive earth pond catfish farms in Africa

Source: Roem, 2014

In South Africa, the catfish production was recorded at approximately 180 tons a year. However, since 2012 there have been no production records available (DAFF, 2016). This lack of information and data is due to the fact that the majority of South African producers do not present their farming data to the relevant governmental departments for reporting purposes. This is depicted in Figure 5-7 below.

Adapted from FAO,2017

Figure 5-7: South African Catfish Production (2006-2014)



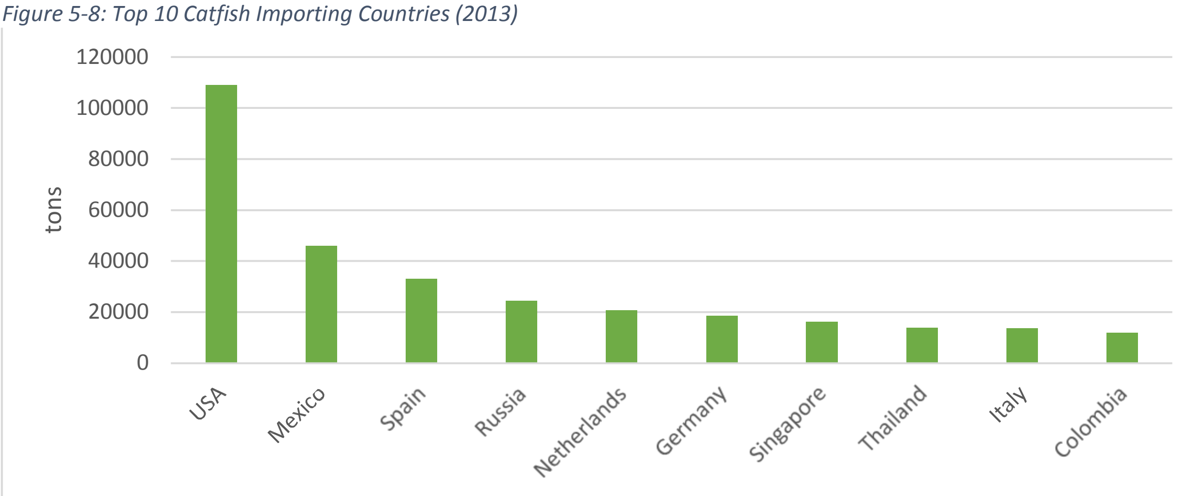
Source: DAFF, 2016

The recent shut down of the South African catfish industry is associated with the farmers closing their operations due to production costs exceeding the selling price, which was a direct result of the high price of feeds (FAO, 2017). The latest report by DAFF (2016), indicates that most farmers are focusing on producing catfish fingerlings for the export market rather than growing the fish to market size.

5.1.2. Global and Regional Consumption Analysis

When considering the overall market demand of all key catfish species, it was revealed that the USA is the leading market globally for catfish. A report produced by the FAO (2016) indicates that during 2013, the USA alone imported more then 100 000 tons. Other sources claim that in the same year (2013), the import of all Catfish goods amounted to over 127 000 tons which counted for 80% of all sales in the USA (Hanson, 2015). This implies that total value of the USA market for 2013 was set at approximately 160 000 tons. Following on the USA market during 2013, were Mexico, Spain, Russia, Netherlands, Germany, Singapore, Thailand, Italy, and Colombia as seen in Figure 5-8 below.

Figure 5-8: Top 10 Catfish Importing Countries (2013)



Source: FAO, 2016

The Asian markets, led by China's demand, is another key international market (China daily, 2017). Fish consumption in China has sharply increased especially within hotels, restaurants, schools, and enterprises. As a result, Vietnam has doubled its exports of Catfish into China to nearly USD 305 million in 2016 (China daily, 2017). The demand for African catfish fluctuates widely in European countries such as the Netherlands, Belgium, and Hungary (FOA, 2017). Contrary to that, the market for African catfish in Sub-Saharan Africa is constantly developing. However, all local production in Sub-Saharan is aimed at the domestic markets. The major producing countries such as Nigeria and Uganda, mainly produce for their own local markets. The demand in these countries are in fact higher than local production where countries are substantial importers of fish aiming to meet their local demand (Banrie, 2012; Premium times NG, 2017). However, there is a lack of information on the consumption patterns globally and within in the sub-Saharan region which makes understanding the dynamics of the catfish trade and markets challenging.

From the limited and fragmented literature and interviews, the following can be concluded:

1. The largest consumption of catfish in the continent is concentrated in the Nigerian market (over 160,000 tons). Further expansion is predicated considering the population size of the country of 186 million and the growth rate of 2.6% a year (Worldometers, 2017; The World Bank, 2017). The growing population coupled with consumption of fish at about 15 kilograms per capita, suggests a total demand for approximately 2.8 million tons a year of fish per annum.

2. Uganda is currently producing and consuming 40,000 tons of catfish. In addition to this, there is a growing demand for the use of catfish as bait by the longline fishery of the Nile perch. An estimate of 3 million bait units per day is required for the region (Uganda, Kenya, and Tanzanian). Within the region, there is limited supply due to the decline of the nature bait resource, implying that this could be a major market for the catfish industry (Maurice, 2010).

3. Countries with the lowest catfish consumption quantities include the DRC, Kenya, Ghana, Cameroon, and Zambia (FAO, 2016; Maurice, 2010; Banda, 2016).

5.1.3. Local Consumption Analysis

Currently, the South African catfish market is extremely small and is estimated to be in the range of about 100 tonnes a year within the Gauteng Province (Personal Communication, 2017). The most consumed products on the local market is fresh and drained whole fish, which is driven mostly by the exports from Western and Eastern Africa. It has been reported that demand now exists within the South African catfish market for value added products such as sausages and burger patties. Additional catfish by-products were reported to be used as animal feed (such as within some crocodile farms) but quantities were extremely low (Personal Communication, 2017).

The local market has immense potential and has the ability to grow much larger considering the large foreign population which resides in South Africa. There are approximately 3 million foreigners, with 100 000 Western and East Africans (Statistics, 2016). However, the true potential of catfish lies in the consumption of value-added products by the South African middle class. Therefore, it is imperative to educate and influence consumer buying preferences through marketing and education.

5.2. Marketing channels

This sub-section will identify the key global, regional, and local marketing channels for Catfish that are important to understand in terms of trade, major producers, and the flow of products between countries. The generic economic model takes both local and international markets into consideration and offers flexible pricing options which are dependent on the size of the fish being produced and the target market identified. The pricing of the fish, and the target market impact on the financial results obtained when using the generic economic model. Understanding the markets, pricing and preferred products for the market is essential.

5.2.1. Global Catfish Trade

The Asian market has been identified as the main global trade channel for catfish species, with Vietnam being the biggest exporter (China daily, 2017). Other key market channels include the USA which imports substantial quantities from Vietnam (China AG, 2017), and the EU market which import from: Vietnam, Indonesia, India, and Brazil. The exporting dynamics is indicated in Figure 5-8(FAO, 2016). As reported by the FOA (2015), the volumes of exported trade of all catfish products (fresh, frozen, whole, and filleted) indicate that Vietnam is the dominant exporter especially when it comes to value added products as seen in Table 5-1 below.

Table 5-1: Top exporting countries of Catfish (2015)

Country	Tonnes
Viet Nam	576,908
China	11,825
Indonesia	7,764
Netherlands	7,385
Belgium	4,669
Germany	4,383
USA	3,869
Thailand	3,223
Belarus	2,712
Portugal	2,584
Spain	1,298

Source: FAO, 2016

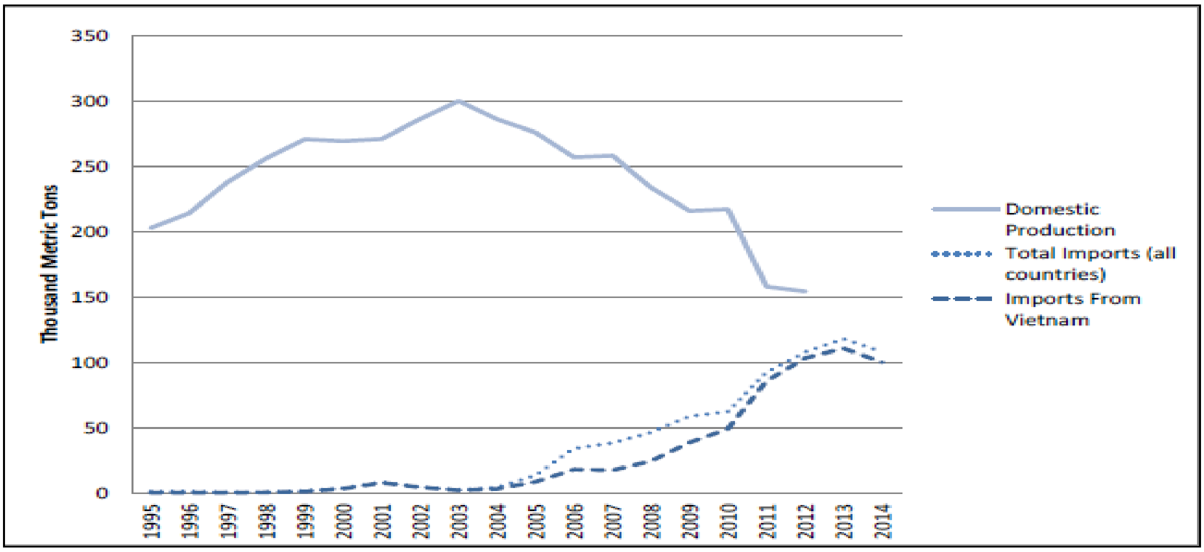
However, the USA industry has experienced a decrease in the local production of catfish as seen in the table below. This is mostly due to the high competition of the importation from Vietnam. These dynamics in the industry also resulted with the market reaching a saturated stage with limited potential to grow further as seen in Figure below (Hanson, 2014).

Table 5-2: USA Catfish consumption kg per capita (2000-2013)

Year	2000	2003	2006	2009	2013
Kg/capita	0.452	0.515	0.439	0.385	0.272

Source: Hanson, 2014

Figure 5-9: USA local production vs. imported Catfish fillet (1995-2014)



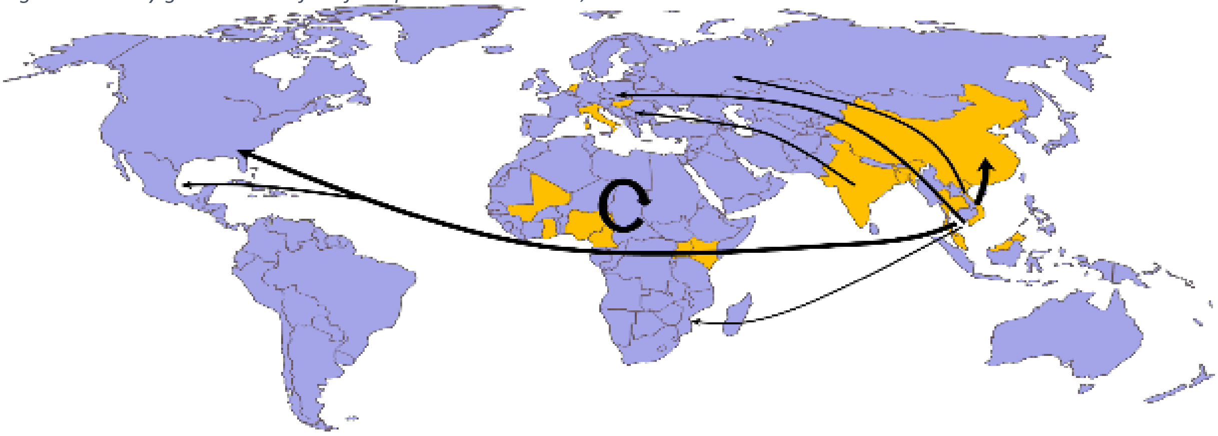
Source: Upton, 2015

In a recent report by China AG (2017), it was noted that:

- In November 2016, Vietnamese catfish exports to the USA were suffering from increased import inspections from US customs and from an anti-dumping duty/tax,
- China become the bigger importer of Catfish than the USA,
- Frozen catfish fillets imported by mainland Chinese between 2014 to 2015 increased from 7,996 tonnes (USD 18.8 million) to 13,569 tonnes (USD 32.5 million), and
- Frozen whole catfish imported by mainland Chinese between 2014 to 2015 increased from 912 tonnes (USD 852,631) to 3,251 tonnes (USD 4.5 million)

Furthermore, the uncontrolled transfer of catfish species by small-scale farmers from Bangladesh to Nepal and India indicates that not all trade is recorded (FAO, 2017). A case in point is the informal trade Sub-Sahara region in Africa (Banda, 2016).

Figure 5-10: Key global trade of Catfish species into the USA, EU and Asia markets



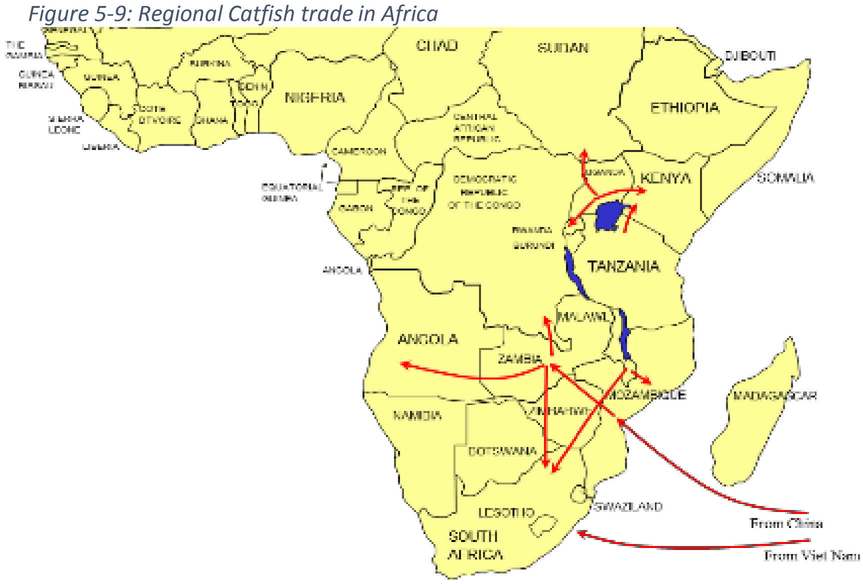
Source: Adapted from EUMOFA, 2016; FAO, 2017; Farm Africa, 2016, FAO, 2016

From the figure above, it is evident that international trade mainly occurs between the Asian and the USA markets. Whereas Catfish producing countries in Africa, (mostly Nigeria and Uganda) are more likely to focus on domestic and regional market trade.

5.2.2. Regional and Local Trade of Catfish

It has been noted that within Africa, catfish trade occurs mostly through informal local markets (similar to Tilapia) and less through formalised trade (supermarkets, fish shops or door to door trade) ((Farm Africa, 2016). There are lucrative market niches for the African catfish in several Sub-Saharan countries. Some worth mentioning are Kenya (which gets supplies from Lake Kiteka in Singinda in Tanzania), DRC, Sudan, Central and West Africa. Zambia exports smoked catfish to the DRC, and to South Africa (mainly for West African communities), and Angola (Figure 5-9) (IOC, 2012). An estimated 5000 tons of Catfish were informally traded in Zambia alone during the month of October 2015, clearly indicating the scale of trade in the Southern African region. Similarly, over 2000 tons of Catfish were informally traded in Malawi which further emphasises the trade scale within the informal market channels (Banda, 2016).

Figure 5-9: Regional Catfish trade in Africa



Source: adapted from IOC, 2012; Farm Africa, 2016, Banda, 2016

The South African catfish industry has a small local market which can be seen as underdeveloped. The local market within South Africa mostly consists of foreigners from the Western and Eastern parts of Africa who are now based in Gauteng (Personal Communication, 2017). Sales are typically done through direct marketing and it is assumed that majority of the catfish supply is imported (considering that there is very limited local production).

A report produced by DAFF indicated that about 3.4 tons of catfish were exported from South Africa in 2016. These exports were mostly into Nigeria and consisted mainly of fingerlings based on price per kilogram (DAFF, 2016; Personal Communication ,2017). In addition to this, approximately 11 tonnes of catfish were imported into South Africa, mainly from Vietnam (90%) and Thailand. Catfish are predominantly imported from Asia and re-distributed into South Africa via Zambia and Malawi (Banda, 2016). The low import price results in further competition to new upcoming small-scale catfish farmers. However, the import supply is mainly targeted at the Western and Eastern African communities and less on new market niches. However, products such as the added-value products could be more suitable for the South African middle-class consumers. From stakeholder consultations, it is evident that additional direct trade was recorded between Asia and South Africa. This is seen through the importation of the Asian 'Shark Catfish' (*Pangasiidae*)which Vietnam processes into fillets and send to South Africa; an estimated of 60 tons a year is supplied to Woolworths (Personal Communication, 2017).

5.3. Market requirements

This sub-section determines the market demands for catfish products (frozen vs fresh) from a global, regional, and local market perspective. Furthermore, it will explore any potential gaps within the market.

5.3.1. Global Requirements

The European market particularly focuses on fresh whole, gutted head off. It is worth noting that the price trend in Europe (particularly Hungary) is stagnant. Table demonstrates the Hungarian market below. The USA market on the other hand, has a mix of value-added filleted fresh and frozen products from its local industry as well as frozen fillets from the Asian importer, mostly Vietnam and China (Hanson, 2014). The Asian market enjoys variety of fresh goods due to the close proximity of the markets to its farms. Such the case with the Vietnam's export into China through its border gates in the three northern provinces of Quang Ninh, Lang Son and Cao Bang (China daily, 2017).

Table 5-3: Prices of African catfish in Hungary 2013-2015

Year	2013	2014	2015
EUR/Kg	*3.32*	*3.59*	*3.36*

Source: EUMOFA, 2016

5.3.2. Regional and Local Requirements

The African Catfish products is sold in various forms in Africa, including: fresh or smoked steaked, filleted, headed, gutted, and skinned. New industrial products include fish sausages which is produced locally (African Union, 2015). These products are illustrated in Figure 5-10 and Figure 5-11. In the sub-Saharan region, market prices range from USD 2.5-5.0/kg; smoked dried fish commanding higher prices (FAO, 2017).

In Nigeria, the current average retail selling price for fresh catfish is USD 3.5/kg, while in Central Africa region, namely Cameroon, Gabon or Democratic Republic of Congo, fresh fish with average size of 500 g is sold for USD 3.3-5.2/kg (FAO, 2017). In South Eastern Africa, catfish prices are lower than those for tilapia. In Kenya prices range from 0.5-1.65 USD/Kg for a fillet of fish whereas a whole fish is sold between 2-2.4 USD/Kg. Due to its affordability, catfish is popular amongst the lower economic class (Farm Africa,2016). Approximately 70% of cultured African catfish is currently sold as fresh whole fish in the continent and is deemed to be the preferred product as it is made in many local dishes. The common catfish African dishes are illustrated in Figure 5. Even though fresh catfish is popular the market is expected to expand through the development of new product forms and value-added processing such as African Catfish sausages (Figure 5-10 below) (FAO, 2017).

Figure 5-12: Local Western African Catfish Dishes

Source: African Union,2015

Figure 5-10:Value- added African Catfish sausages

Source: African Union,2015

Figure 5-11: Smoked Catfish fillets at local supermarkets

Source: Maurice,2010

In South Africa, the African catfish is not a popular fish or good seller. The local market is limited to foreigners, mostly from the West African countries, residing in South Africa (FAO, 2017). Some of the preferred products are fresh, smoked, and dried whole fish. These usually sell at a relatively low price of about R15-20/Kg (wholesale price) (Personal Communication, 2017). To develop the local market in South Africa, an innovated approach will be required, with a focus on value-added products. The competition is tough considering there are existing pelagic fish products such as Hake and Pilchards. Figure 5-12 illustrates some of the value-added products that can be manufactured to

Figure 5-12: South African value-added catfish products

transform the South African market.

Source: Urban-Econ, 2017; Cajun Catfish Farm, 2017

New value-added products such as fish burger and fish sausages (Figure 5-12 above) through direct marketing are already getting a good respond from the market at acceptable prices (Personal Communication, 2017). Value-added products are predominantly found in large retailers in South Africa, and are targeted towards middle income earners, however this market could be expanded in the future.

5.4. Barriers to entry and limitations of the market

Barriers to entry, and market limitations are an important consideration when looking at the feasibility of a product. Market saturation, trade barriers, market competition and potential market restrictions are important aspects to consider for this market assessment.

5.4.1. Market Saturation

Globally, both the EU and the USA catfish markets seem to be saturated and highly competitive, with Asia being the primary supplier and dominant producer. Evidence of the strong competition can be noticed by the established and declining local USA industry (Upton, 2015). On the other hand, the African market is still in its infant stages and depicts a higher demand than the current supply. These market conditions mostly apply to countries such as Nigeria, Uganda, Kenya, and DRC. The South African market on the other hand, is a very small market in comparison to the other African countries, and presently relies on the exports from African countries. This market is being supplied by both, informal traders in Gauteng (who received their supply from Zambia and Malawi), and some retail stores such as Woolworths (who import value-added fillet from Asia). The existing demand and low price could imply that the market is not fully saturated but rather subject to competition by the importation.

5.4.2. Competition

The Asian producers led by the Vietnamese, offers vicious competition to any new entrant to the catfish industry. Their industry is well positioned to provide value-added processed fillets at a competitive pricing (due to their lower production costs). In South Africa, the price for whole fish is particularly low (set at about R15-20/kg) and is mostly driven by the supply of imported goods. This implies that local production cannot compete with imported products due to high cost of production. Therefore, the opportunities for South Africa could be found by developing new value-added products that will appeal to the South African consumers (such as fish wors, pickled, canned). The pricing for catfish will need to be addressed as the fish have bad stigma in South Africa (an association with low meat quality and cultural perceptions). An innovative and substantial marketing campaign will be required to change the perceptions of fish consumers in South Africa (Personal Communication, 2017).

5.4.3. Logistical Challenges

Due to poor and limited infrastructure (roads, cold chain systems for food preservation etc.) in many African countries, the market distribution of catfish into African markets may be affected. For example, the DRC market offers an opportunity for trade, provided suppliers can access the various fish markets centres in the country (Personal Communication, 2017). There is a lack of cold chain infrastructures some of which includes: storage facilities, refrigerated trucks and trains, within the sub-Saharan region. This creates a critical bottle-neck in transportation of fresh goods from the expanding farms. However, the case in South Africa is different. The infrastructure required are in better conditions, providing an opportunity for producers to reach potential local urban markets in major cities.

5.4.4. Trade and Business Restrictions

Within the USA and the EU markets, there are very strict market conditions for catfish trade including permitting, quality conditions, health inspection. The South African aquaculture sector lacks a regulated system that is approved by the EU or the USA to monitor quality of farm production. As a result, exporting these farmed products without certified farms products to the EU and USA could prove to be problematic. South African officials reveal that a possible ban exists on exporting to the EU market Such a limitation could be resolved with the introduction of certified labs to examine the required test on each farm (Personal Communication, 2017).

The Nigerian government have plans in place to introduce a ban on fish imports to protect their local catfish industry (Premium times NG, 2017). This could be an issue if export into Nigeria is considered. However, the Nigerian dependency on importation of fish products is currently too high (due to high domestic demand) and such a ban would not be realistic.

5.4.5. Market Immaturity

The South African market is currently too small and immature to observe any significant commercial production. In South Africa, the entry into market is rather difficult and risky due to the low consumption of fish per capita, low prices received, and the overall dislike of catfish in the local market. Regional export markets are more mature and able to absorb a supply of Catfish (such as Zambia, DRC, and further on in Nigeria). Based on the limited local data available, it is difficult to assess how the African sharptooth catfish imports being sold at the large retail chains affect the local market, and whether the local market would be able to meet the demands of retailers should the production volumes in South Africa increase. Market immaturity is a key challenge for the African sharptooth catfish industry in South Africa, and special attention is required to develop the local market and improve consumer perceptions and interest in this industry.

5.5. Market Analysis: Conclusion and Recommendations

The local South African market is very small and requires a creative value-added production approach to develop significant demand and out compete local equivalent supply such as the Pelagic Fishery, Pilchards (Urban Econ, 2015). Local retail stores have shown an interest to become an offtake provided supply is steady and price is suitable.

Local South African markets could expand to include specific value-added market products, such as Catfish wors, sausages, and burger patties (which are currently being successfully tested in the local market). Possible exporting into Nigeria and other surrounding countries could open new market channels, provided the pricing is correct. If the product is unique and able to compete with other fish products, then additional export to Asia should be considered.

Furthermore, a large market for bait exists in East African around Lake Victoria for Uganda, Kenya, and Tanzania. Additional analysis and research would be needed to assess these market opportunities including, prices, supply chain and logistics aspects. Supporting the local industry and possibly exporting fingerlings to catfish producing countries in Africa is an alternative option for the South African catfish industry to consider seeing that demand for catfish fingerlings is high.

In conclusion, the South African Catfish industry could become a thriving industry provided off takers are clearly identified (locally, regionally, and internationally) and production operations collaborate (e.g.: cooperative, etc) to ensure they can access the market more effectively and that they are in line with the off takers requirements, in terms of price, quality and supply.

6. SWOT analysis for the African Sharptooth Catfish

6.1. SWOT Analysis

Table 6-1 below presents the strength, weaknesses, opportunities, and the threats faced by the African sharptooth catfish industry in South Africa.

Table 6-1: African Sharptooth Catfish SWOT Analysis

Strengths	Weaknesses
• High resistance to diseases • High ability to withstand stress • Highly valued food fish in Africa • Wide eating habits • Wide tolerance of temperatures and water quality • Can be grown in high stocking densities • Air breathing qualities	• Specialised techniques are required for breeding • In pond culture systems they can escape easily • Require high protein feed • Not widely accepted on the markets • Palatability can be reduced with larger fish • Juveniles can exhibit cannibalism leading to stock loss
Opportunities	**Threats**
• Several agro-processing opportunities to expand into • Growing demand for catfish fingerlings in Africa • Good export market channels • Linkages with tourism • Growing demand for an affordable protein source • Shortage in traditional fisheries products	• Faces high competition from other freshwater species on the markets • Shortage of extension services, technical skills, and support • Complex resource-based legislation • Potentially require permit costs with change in NEMBA classification • Lack of the right technology and high technology costs • Shortage of suitable freshwater resources

The generic economic model considered some key weaknesses and threats that would impact on profitability. The model assists with developing a risk profile for producers which is used to determine interest rates and loan repayments based on education levels and skills, and access to land, infrastructure, and facilities. Factors such as permit costs are built into the model to mitigate the risk of unexpected costs that may arise from obtaining permits. Marketing of catfish is crucial to the profitability and success of an operation, and producers should consider marketing and packaging when doing their financial and business planning.

6.2. Mitigation Measures

The mitigation measures identified in the table below aim to address the threats and weaknesses identified in the SWOT analysis discussed above. It is essential for African sharptooth catfish producers to take note of the potential risks and weaknesses identified to ensure they can implement mitigation measures and understand the challenges they may face.

Table 6-2: African sharptooth catfish Mitigation Measures

Risks Identified	Mitigation Measures
1. Breeding of African sharptooth catfish in aquaculture systems	• Training and skills development for producers can improve captive breeding success rates • Aquaculture extension services should be equipped to assist producers • Improved farm management are required to increase

Risks Identified	Mitigation Measures
	breeding success
2. Under developed value chain	• Research and development is required to develop the value chain specifically looking at feed quality, costs of inputs and access to inputs • Inputs should be ideally accessible country wide, and near to producers • Identify location of producers versus location of input suppliers to establish depots or delivery networks to reduce costs
3. Market Acceptance & Consumer preference	• Develop marketing strategies or campaigns to change the negative perception surrounding catfish • Public campaigns to promote consumption of fish should be encouraged • Encourage retailers to promote and stock catfish products and processed goods • Study African markets to understand how and why catfish flourishes in select African countries compared to South Africa
4. Farm management	• Improved access to skills and training on catfish production • Develop strategic guidelines specific to catfish production in South Africa • Facilitate engagements or discussions between government, producers, and stakeholders to improve farm management and production of catfish
5. Freshwater industry competition	• Linked to improved marketing and a change of perception of catfish • White meat fish are popular in South Africa, and through improved marketing and appearance of catfish products in retail outlets, consumption could be increased • Prices for catfish are lower than other freshwater fish products, thus they should be more competitive
6. Risk of catfish landing up in natural water bodies/systems	• Provide system design guidelines and biosecurity measures that are required within South Africa • Training and education for new catfish producers on risks of escape from aquaculture operations • Conduct site visits to assess existing aquaculture operations biosecurity measures • New catfish operations should meet minimum standards before being approved
7. Permits and Regulations	• Clarification on NEMBA AIS classification for catfish should be finalised and communicated to the industry • Permit and regulatory applications should be streamlined to avoid lengthy delays and costs for producers • Permits and regulations should support the development of the aquaculture industry, and ensure environmental sustainability is maintained

7. African Sharptooth Catfish Technical Assessment

The technical assessment below provides a summary of the assumptions used within the economic model for catfish as well as data presented in the species overview and biological characteristics. The technical assessment covers the following information:

- Water conditions,
- Broodstock/Breeding,
- Genetic selection,
- Hatchery/fry production,
- Production performance, and
- Additional information.

Table 7-1: African sharptooth catfish technical assessment

	Overview
Latin name	*Clarias gariepinus*
Common name	Sharptooth catfish, Barbel
Biological requirements	
Salinity	17 to 32˚C salinity: 0 to 12 ppt, 0 to 2.5 ppt is optimal.
Temperature	Tolerance 8 to 35°C. Breeding >18°C water temperature range for egg hatching.
Broodstock/breeding	
Spawning	Catfish mature at about the age of 12 months. Under stable environmental conditions, adult C. gariepinus have mature gonads year-round. Under ideal conditions, a ripe female may lay about 60 000 eggs/kg.
(Natural/induced)	African catfish reproduce in response to environmental stimuli such as a rise in water level and inundation of low-lying areas. These events do not occur in captivity, and hormone treatment is employed to ensure large-scale production of catfish fingerlings. The hormones used include ovaprim, deoxycorticosterone acetate (DOCA), human chorionic gonadotropin (HCG), and fish pituitary glands.
Egg size	The eggs are adhesive and hatch in 20-60 hours, depending on temperature. The yolk sac is absorbed within three to four days, and the stomach is fully functional within five to six days after onset of exogenous feeding.
Genetic selection	The African Catfish are easily crossed with *Heterobranchus longifillis* to produce hybrid called Hetero-Clarias. This crossbred advantages over C. gariepinus, however from an environmental aspect, hybridisation of Catfish is not supported.
Hatchery/fry production	
Hatchery system	Fry (0.05-0.1 g) are fed with Artemia and 0.25 mm fry feed for 14 days in 100-1 000 litre tanks (600 g/m^3 stocking density). Then, advanced fry (0.1-1 g), stocked at 10 000/m^3, are fed 0.3-0.8 mm dry feed for 26 days in 600-1 000 litre tanks. Juveniles (1-8 g) are reared in 600-6 000 litre tanks at 400/m^3 for 20 days and fed 0.8-1.5 mm dry feed. Large-scale hatcheries with intensive recirculation systems, using genetically-improved broodstock. Fry are kept at 5 000-15 000/m^3
First feed requirement	Live feeds (Brachionus, Moina, Daphnia, Artemia).
Hatchery survival	Up to 75% fish to egg survival is recorded.
Production performance	
Typical FCR	1.1:1 food conversion ratio range 0.9 to 1.3:1.

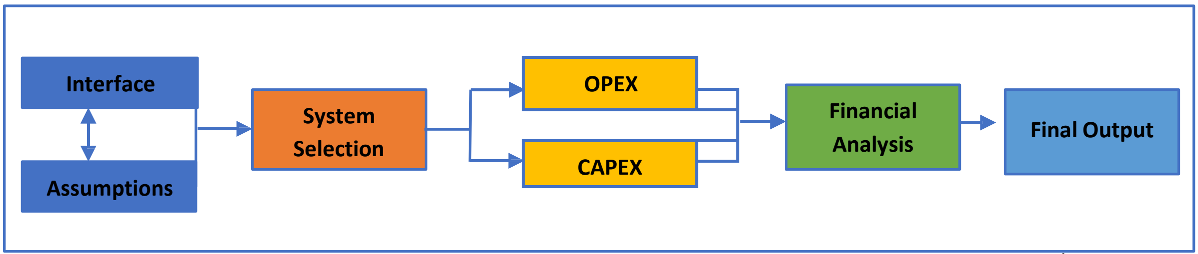
	Overview
Feed requirement	The optimal diet should have a high protein content and the correct amino acid balance. Clarias gariepinus has a high level of enzyme activity in its digestive tract and relies primarily on enzymatic digestion, rather than acid hydrolysis, to digest its food. The best growth rate and FCR are achieved with diets containing 35-42% crude protein and 12 kJ/g feed. Extruded feeds that float cause less pollution and are more efficient.
Feed Consumption	• % of fish/mass/day (Month 1) - 4.8% • % of fish/mass/day (Month 2) – 4.1% • % of fish/mass/day (Month 3) – 3.7% • % of fish/mass/day (Month 4 – 2%) • % of fish/mass/day (Month 5) – 1.6% • % of fish/mass/day (Month 6) – 1.3% • % of fish/mass/day (Month 7+) – 1.2%
Typical Survival Rate	Typically, 75% to 90% during grow-out. 90% is used in the generic economic model.
Typical growth Rate	Fish can be reared to 1 kg in six to nine months. The generic economic model assumes 1 kg weight will be reached by Month 8.
Diseases	African sharptooth catfish are subject to a wide variety of diseases including bacteria, fungi, and miscellaneous parasites. Some of the most important disease organisms are included in the table below, though many of the observed diseases are yet to be fully diagnosed. Most of the diseases are principally observed within intensive culture. Prevention through avoidance of stress is probably the most effective means of avoiding diseases. So far, virus related diseases have not been reported in African catfish.
Production	
Production systems	• **Ponds:** Circular RAS tanks (nursery) and earthen grow-out ponds • **RAS:** Circular, plastic grow out tanks • **Raceway:** Concrete grow out tanks • **Cage:** Circular RAS tanks (nursery) and floating cages • **Flow-through & Aquaponics:** linear, lined tanks
Processing and markets	
Product form	• Dried • Processed (hamburger patties, sausages etc) • Fresh – pieces/fillets
Additional Information	
Research and development required	• Genetic improvement of broodstock • Feed manufacturing & quality • Feeding habits & food use efficiency • Co-cultivation of catfish with other species • Changing the market perception of catfish
Environmental impacts	Impacts from flow-through systems are largely from disease treatment chemicals, uneaten feed, and fish excreta, which can alter water and sediment chemistry downstream of the farm. Elevated nutrients reduce water quality (increasing biological oxygen demand, reducing dissolved oxygen, and increasing turbidity) and increase the growth of algae and aquatic plants.

8. African Sharptooth Catfish Financial Analysis

8.1. Introduction

The generic economic model provides users with the opportunity to individual producer data, proposed production volumes and scales and financial data. Through the model, the users will receive financial outputs which include capital and operational costs and financial indicators which will guide the user in determining whether the proposed aquaculture project is feasible, and a viable investment opportunity. A high-level overview of the model process can be seen in the figure below.

Figure 8-1: Generic Economic Model Overview



Source: Urban-Econ,2018

The generic economic model can be customised to provide results for individual producers based on selections made with regard to the location of the aquaculture operation (at a provincial level), type of operation (start-up or existing), the scale of operation, type of production system, size and pricing of the Catfish, education level and type of financing that will be used (equity or debt/equity).

8.2. Key Economic Model Assumptions

The generic economic model for the African sharptooth Catfish was developed using data from various information sources, consultations with various stakeholders and industry experts, and through inputs gathered at two peer-review workshops conducted.

8.2.1. Production Assumptions

To develop the generic economic model, specific production assumptions were identified and utilised. Some key assumptions used can be seen in Table 8-1 below.

Table 8-1: African Sharptooth Catfish Production Assumptions

Catfish fingerlings	• R 1.50 (less than 20 000 per order) • R 1.36 (more than 20 000 per order)
Maximum Production cycle length	8 months
Survival Rate (8 months)	90%
Mortality Rate (8 months)	10%
Average Feed price	R12/kilogram.

Industry experts recommended the assumptions seen above, however, they may differ from farm to farm. Prices are based on 2017/2018 prices and are subject to change over time. Producers should be encouraged to establish relationships with suppliers to benefit from bulk prices, specifically at larger tonnages.

8.2.2. Capital Expenditure

The capital expenditure costs for Catfish production focused on the establishment of the potential production systems identified for Catfish production in South Africa. The capital expenditure is determined by the scale of production, and the selected production cycle length. Some of the key factors to note include the following:

a. **Pre-development costs** for construction phase, concept design, specialist consultations, town planning alignment (zoning, rezoning etc.), and development of bulk infrastructure (roads, installation of electricity to the site, bulk water services etc.) were excluded from the model as this is site specific and not suitable to model at a provincial level,
b. **Land costs** were included should an individual/business not have an existing farm. Based on average farm prices for 2017/2018, a per hectare (ha) rate of R 246 346 was used.
c. **Services** such as the costs of water and electricity were included in the model, and vary between the nine provinces,
d. **Buildings** such as storerooms, offices, cold storage, and a feed room were considered,
e. **Aquaculture system** costs focused on the development of the five production systems,
f. **A storage dam** was included in the capital expenditure costs for selected production systems.
g. **Infrastructure costs** are calculated as a once-off, lump sum amount to be spent in year one, however a producer can choose to phase in production which would spilt the costs up depending on how the production is phased in.

8.2.3. Operational Expenditure

Operational expenditure, or working capital was determined by looking at the variable costs of production, and fixed costs. Costs can be divided into fixed and variable costs. **Variable costs** include fingerlings, fertilisers (where required), feed, transport, and water costs. It should be noted that it is was assumed that aquaculture producers in South Africa are currently not charged for water unless using municipal water sources (DAFF,2018).

Fixed Costs include costs such as salaries, insurance, electricity, legal/licensing costs, veterinary services, and general expenses (telephone, electricity, health and safety apparel, stationery etc.). Reserve and unforeseen costs have also been included (calculated at 2% of the variable cost total).

8.2.4. Scale of production

From the generic economic model, two production volumes were identified. Firstly, the minimum production volume which indicates at what tonnage a producer would first be profitable. Secondly, the optimal production tonnage was identified, which indicates where the optimal return on investment and profitability is achieved.

8.2.5. Market Information

The African sharptooth catfish market information was based on industry experts and research conducted. The average farm gate price for the African sharptooth catfish ranges from R 15 to R 19 per kilogram in South Africa, however through the results obtained by the generic economic model, specific price ranges have been identified for each production system, thus pricing is specific to the production system selected and is discussed in more detail in the sections below.

8.3. African Sharptooth Catfish Production: Financial Overview

Using the generic economic model and the assumptions listed in Table 8-2 below, a financial analysis was conducted for the African sharptooth catfish in each potential production system identified.

Table 8-2: African sharptooth catfish financial and production assumptions

Province	Eastern Cape
Market	Local
Operational Status	Start-up farmer with no existing farm, facilities, or infrastructure
Skills Level	Formal education (certificate/diploma)
Payback Period	20 years
Financing Option	Debt/Equity with an investor (surety)
Debt Percentage	20%
Production Cycle	8 months/1000 grams
Additional Information	• The models exclude the construction phase. The models consider from when production starts. • The model excludes consultancy, contractors, and specialised service provider fees, with the exception of veterinary services.

It is important to note that the results below are unique for each system and based on the results obtained from the generic economic model. The average selling price identified is based on the outcomes from the model and may not be identical to current market prices. When considering African Sharptooth Catfish it is essential to consider the target market, demand, and a realistic selling price to ensure the project is sustainable.

The land size identified above is calculated based on the minimum infrastructure footprints. As each aquaculture operation will differ according to layout, design, and infrastructure requirements, the land size should be used as a guideline for the minimum size property.

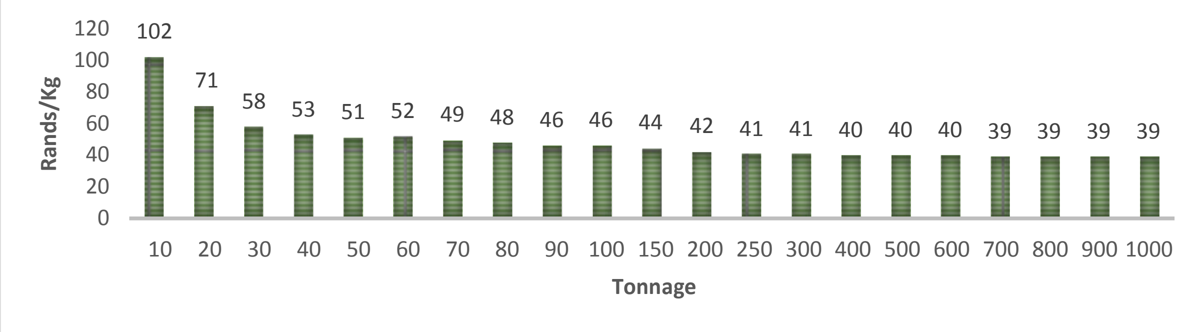
8.3.1. Recirculating Aquaculture System

The recirculating aquaculture system (RAS) is the first of the six models that will be analysed below. A RAS is known for high operating costs which can be attributed to the high electricity usage for pumping and general operation of the system, as well as feed costs associated with artificial feed sources being the primary food source. With regards to infrastructure costs, RAS require temperature control measures and heating equipment, as well as tunnel system to assist with reducing electricity consumption and maintaining a constant water temperature. Based on the assumptions presented in Table 8-2 above, the results obtained from the generic economic model for the RAS are discussed in the section below. Based on the model the minimum tonnage, and optimal tonnage have been identified as well as pricing recommendations.

8.3.1.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the African sharptooth catfish ranges from R 15 to R 19 per kilogram in South Africa, however based on the generic economic model results, it is evident that at these prices, it would not be profitable for a start-up producer to produce African Sharptooth Catfish on a large scale. Figure 8-2 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-2: African sharptooth catfish: RAS Selling Price vs Production Volume



Source: Urban-Econ,2018

Based on the image above, it can be seen that the selling price for the African sharptooth catfish ranges from R 39/kg when producing 700 to 1000 tons per annum, to R 102/kg when producing 10 tons per annum. Based on the results above, the average selling price for catfish in South Africa was identified at R 48/kg when producing in a RAS.

From the generic economic model and information presented above, the minimum profitable tonnage was identified at 66 tons per annum when selling the catfish at the average price of R 48/kg. The optimal return on investment was identified at 977 tons where producers could experience the highest return on investment when selling the catfish at the average price of R 48/kg.

8.3.1.2. Capital Expenditure

Table 8-3 below provides a summary of the infrastructure and built environment costs required to establish a RAS for Catfish production.

Table 8-3: RAS Capital Expenditure (Year 1)

Production Scale	Minimum 75 tons	Optimal 977 tons
Purchasing of land	R 275 223	R 561 737
Infrastructure (Buildings & Tunnels)	R 1 383 450	R 3 694 420
RAS Infrastructure	R 563 442	R 5 898 278
Additional equipment	R 304 695	R 1 639 190
Total Capital Expenditure	**R 2 551 312**	**R 11 936 625**

8.3.1.3. Operational Expenditure

Table 8-4 below provides a summary of the operational costs required for African sharptooth catfish production. The operational expenditure is shown for the first year of operation.

Table 8-4: RAS Operational Expenditure for African sharptooth catfish production (Year 1)

Production Scale	Minimum 75 tons	Optimal 977 tons
Variable costs	**R 1 157 269**	**R 15 050 103**
Catfish fingerlings	*R 129 469*	*R 1 686 906*
Feed	*R 564 423*	*R 7 352 546*
Water Quality Consumables	*R 11 250*	*R 146 550*
Fixed Costs	**R 1 363 901**	**R 7 844 492**
Total Operational Costs	**R 2 511 170**	**R 22 894 595**

Based on the table above, it is evident that feed costs account for an estimated 20 to 30% of the total operational expenditure (depending on the tonnage). Currently in South Africa, fish feed is manufactured by one or two key commercial feed producers, alternatively producers make up their own feed mixes. Feed is a crucial aspect of an aquaculture operation as it can impact on the growth rates, health and quality of the fish produced. Feed prices were estimated to be R12 per kilogram (based on stakeholder consultations), however, producers should investigate the possibility of bulk discounts from feed suppliers. Water consumable costs are linked to water testing equipment (catered for under the Capital Expenditure). These consumables include testing strips, and any chemicals required for the equipment to function. These costs are once off and are not scaled as the equipment used is a standard size regardless of the tonnage being produced.

8.3.1.4. RAS Financial Overview

Table 8-5 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-5: RAS Financial Overview

Production Scale	Minimum 75 tons	Optimal 977 tons
Financial Indicators		
Total Capital Expenditure	R 3 937 448,43	R 22 676 956,78
Loan Amount – Working Capital	R 1 389 024,65	R 10 740 331,38
Loam Amount - Infrastructure	R 2 548 423,78	R 11 936 625,39
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,03	15,14
Internal Rate Return (IRR)	8%	78%
Net Present Value (NPV) over 10 years	R 4 073 990,97	R 343 236 045,12
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	1,12	2,28
Number of fingerlings required	7 194	93 717
Number of employees (Year 1)	8	53

The minimum profitable tonnage was identified at 75 tons per annum when selling the fish at R 55/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with a RAS, with an estimated R 3 937 448 required to meet the minimum profitable tonnage, while the optimal production level of 800 tons per annum would require a capital investment of R 30 494 313 for a start-up producer.

A key factor is the operational costs (specifically feed and transport costs), as well as the infrastructure required for the RAS. The establishment of tunnels for temperature control, RAS ponds, heating equipment and the costs of running the system require a producer to be able to sell the catfish at either R 48/kg when producing 66 tons.

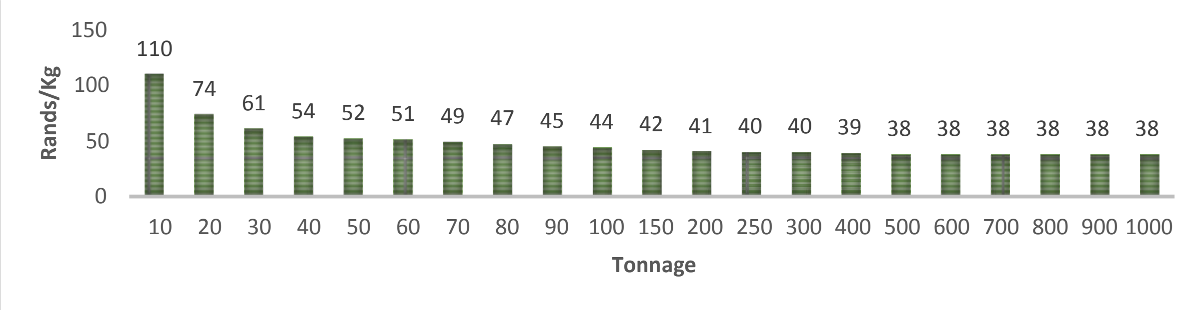
8.3.2. Pond Culture

Pond culture is a common production system for African sharptooth catfish cultivation and is used in a number of countries as their primary production system. It is important to note that when using a pond system, the first two months of the production cycle take place in RAS tanks to ensure the catfish are strong, and large enough to survive in the pond system. The RAS tanks act as 'nurseries' for the catfish and play an important role in the production and growth cycle of the African sharptooth catfish.

8.3.2.1. Price Sensitivity

As discussed previously, the average farm gate price for catfish ranges from R 15 to R 19 per kilogram, however, as with the RAS, these prices are not profitable when using the generic economic model. The graph below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-3: African sharptooth catfish: Pond Culture Selling Price vs Production Volumes



Source: Urban-Econ,2018

Based on the figure above, it can be seen that the selling price for the African sharptooth catfish ranges from R 38/kg when producing 500 to 1000 tons per annum, to R 110/kg when producing 10 tons per annum. Based on the results above, the average selling price for catfish in South Africa was identified at R 48/kg. Based on the figure above, the minimum profitable tonnage was identified at 71 tons. The optimal return on investment when selling at the average price of R 48/kg was achieved at 962 tons.

8.3.2.2. Capital Expenditure

Table 8-6 below provides a summary of the infrastructure and built environment costs required to utilise pond culture for African sharptooth catfish production.

Table 8-6: Pond Culture Capital Expenditure

Production Scale	Minimum 71 tons	Optimal 962 tons
Land Purchase	R 614 517	R 940 809
Infrastructure (Buildings & Storage Dam)	R 1 473 910	R 3 710 610
Pond/RAS System	R 983 957	R 2 020 097
Additional equipment	R 299 106	R 1 580 010
Total Capital Expenditure	**R 3 386 490**	**R 8 287 726**

8.3.2.3. Operational Expenditure

Table 8-7 below provides a summary of the operational costs required for African sharptooth catfish production. The operational expenditure is shown for the first year of operation.

Table 8-7: Pond Culture Operational Expenditure for Catfish Production (Year 1)

Production Scale	Minimum 71 tons	Optimal 962 tons
Variable costs	**R 1 124 660**	**R 14 864 485**
Catfish fingerlings	*R 122 590*	*R 1 648 424*
Fertiliser	*R 29 000*	*R 58 000*
Feed	*R 534 320*	*R 7 239 662*
Water Quality Consumables	*R 10 650*	*R 144 300*
Fixed Costs	**R 1 227 624**	**R 6 734 792**
Total Operational Costs	**R 2 352 284**	**R 21 599 278**

As mentioned with the RAS, feed costs account for an estimated 20 to 30% of the total operational expenditure (depending on the tonnage). Currently in South Africa, fish feed is manufactured by one or two key commercial feed producers, alternatively producers make up their own feed mixes. Feed is a crucial aspect of an aquaculture operation as it can impact on the growth rates, health and quality of the fish produced. Feed prices were estimated to be R12 per kilogram (based on stakeholder consultations), however, producers should investigate the possibility of bulk discounts from feed suppliers.

8.3.3. Pond Culture Financial Overview

Table 8-8 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-8: Pond Culture Financial Overview

Production Scale	Minimum 71 tons	Optimal 962 tons
Financial Indicators		
Total Capital Expenditure	R 4 691 795,61	R 18 251 986,05
Loan Amount – Working Capital	R 1 305 304.69	R 9 964 259,57
Loam Amount - Infrastructure	R 3 386 490,92	R 8 287 726,48
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,09	20,86
Internal Rate Return (IRR)	8%	94%
Net Present Value over 10 years	R 5 093 973,64	R 378 489 335,33
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	2,5	3,8
Number of fingerlings required	6 811	92 278
Number of employees (Year 1)	7	52

The minimum profitable tonnage was identified at 71 tons per annum when selling the fish at R 48/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with a pond system, with an estimated R 4 691 795 required to meet the minimum profitable tonnage, while the optimal production level of 962 tons per annum would require a capital investment of R 18 251 986 for a start-up producer.

The pond system considered includes RAS grow-out tanks for the 10 to 100-gram fish, and earthen ponds for the 100 gram or larger fish, thus while the initial capital expenditure may be costly, the operational expenditure associated with pond culture is lower than that of the RAS or flow-through systems, specifically with regard to the electricity usage.

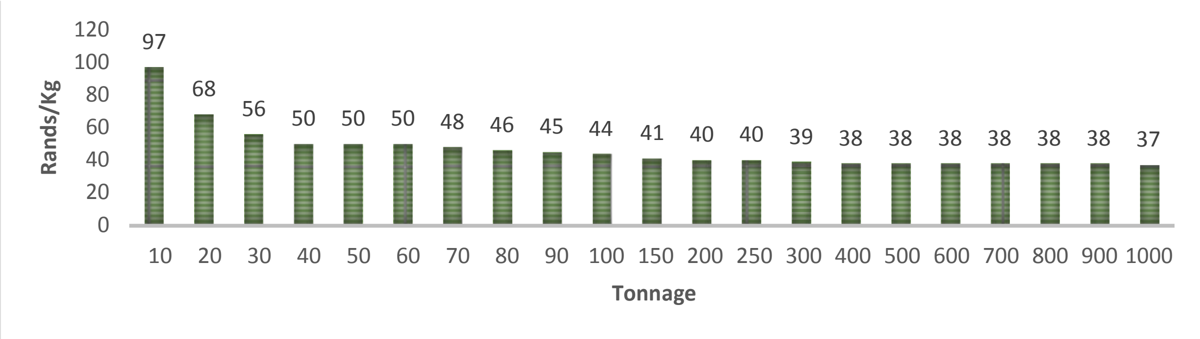
8.3.4. Cage Culture

Cage culture as a production method has fewer operating costs than other production system, specifically when looking at electricity, and water costs.

8.3.4.1. Price Sensitivity

As discussed previously, the average farm gate price for catfish ranges from R 15 to R 19 per kilogram, however, as with the RAS, these prices are not profitable when using the generic economic model. The graph below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-4: African Sharptooth Catfish: Cage Culture Selling Price vs Production Volumes



Source: Urban-Econ,2018

Based on the image above, it can be seen that the farm gate price for the African sharptooth catfish ranges from R 38/kg when producing 600 to 900 tons per annum, to R 97/kg when producing 10 tons per annum. Based on the results above, the average farm gate price for the African sharptooth catfish was identified at R 47/kg. The minimum profitable tonnage was identified at 72 tons when selling the fish at the average price of R 47/kg, and the optimal return on investment being achieved at 940 tons.

8.3.4.2. Capital Expenditure

Table 8-9 below provides a summary of the infrastructure and built environment costs required to utilise cage culture for African sharptooth catfish production in South Africa.

Table 8-9: Cage Culture Capital Expenditure

Production Scale	Minimum 72 tons	Optimal 940 tons
Purchase of land	R 255 909	R 274 606
Infrastructure (Buildings)	R 1 272 853	R 3 324 153
Cage Culture system	R 999 898	R 12 752 708
Additional equipment	R 390 189	R 1 376 2188
Total Capital Expenditure	**R 2 932 850**	**R 17 762 486**

8.3.4.3. Operational Expenditure

Table 8-10 below provides a summary of the operational costs required for African sharptooth catfish production. The operational expenditure is shown for the first year of operation.

Table 8-10: Cage Culture Operational Expenditure (Year 1)

Production Scale	Minimum 72 tons	Optimal 940 tons
Variable costs	**R 1 100 262**	**R 14 339 219**
Catfish fingerlings	*R 124 317*	*R 1 623 022*
Feed	*R 541 846*	*R 7 074 098*
Fixed Costs	**R 1 289 397**	**R 6 520 995**
Total Operational Costs	**R 2 389 659**	**R 20 860 214**

As mentioned previously, feed costs account for an estimated 20 to 30% of the total operational expenditure (depending on the tonnage). Currently in South Africa, fish feed is manufactured by one or two key commercial feed producers, alternatively producers make up their own feed mixes. Feed is a crucial aspect of an aquaculture operation as it can impact on the growth rates, health and quality of the fish produced. Feed prices were estimated to be R12 per kilogram (based on stakeholder consultations), however, producers should investigate the possibility of bulk discounts from feed suppliers.

8.3.4.4. Cage Culture Financial Overview

Table 8-11 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-11: Cage Culture Financial Overview

Production Scale	Minimum 72 tons	Optimal 940 tons
Financial Indicators		
Total Capital Expenditure	R 4 245 235,19	R 27 276 854,48
Loan Amount – Working Capital	R 1 312 384,74	R 9 514 367,87
Loam Amount - Infrastructure	R 2 932 850,45	R 17 762 486,60
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,07	13,21
Internal Rate Return (IRR)	8%	75%
Net Present Value over 10 years	R 4 540 671,62	R 360 398 793,40
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	1	1,1
Number of fingerlings required	6 906	90 168
Number of employees (Year 1)	8	33

The minimum profitable tonnage was identified at 72 tons per annum when selling the fish at R 47/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with cage culture, with an estimated R 4 245 235 required to meet the minimum profitable tonnage, while the optimal production level of 940 tons per annum would require a capital investment of R 27 276 854 for a start-up producer. The costs associated with establishing and operating a cage culture operation are far lower than any of the other systems, which is linked to less infrastructure requirements, much lower day-to-day operational costs as well as a reduced demand for land, electricity, and additional expenses such as fertilisers or tunnels.

The cage culture system in the generic economic model includes RAS grow-out tanks for the 10 to 100-gram fish, and floating cages for the 100 gram or larger fish.

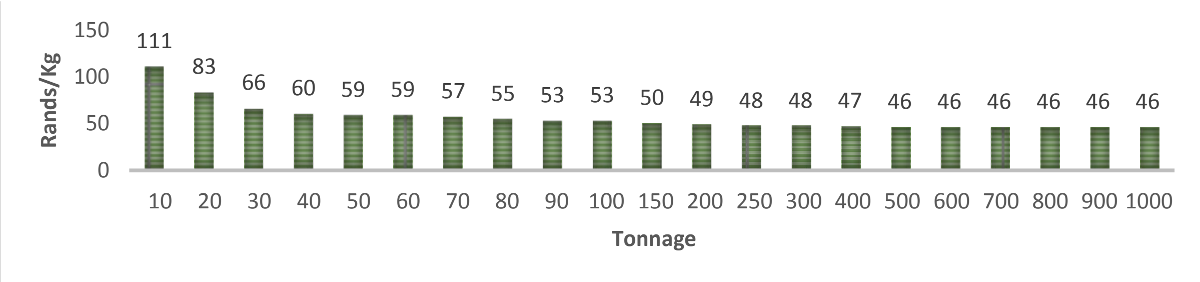
8.3.5. Flow-through Systems

Flow-through systems differ from RAS or pond system as they require continuous, fast-flowing water through the system. With this in mind, the model assumes that continuous pumping will be required from a suitable water source, with additional measures such as heating equipment and tunnels excluded from the costing as it would not be effective to heating water continuously leaving the system. Consideration should be made for a settlement pond or wetland area to prevent environmental risks and degradation and reduce the risk of fish from the aquaculture operation entering natural water bodies.

8.3.5.1. Price Sensitivity

The generic economic model clearly identifies the key role price (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price identified during the project was R35 per kilogram, however based on the generic economic model results, it is evident that at R35/kg, it would not be profitable for a start-up producer to produce catfish. The graph below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-5: African sharptooth catfish: Flow-through Selling Price vs Production Volume



Source: Urban-Econ,2018

Based on the image above, it can be seen that the selling price for the African sharptooth catfish ranges from R 46/kg when producing 500 to 1000 tons per annum, to R 111/kg when producing 10 tons per annum. Based on the results above, the average selling price for catfish in South Africa was identified at R 56/kg when producing in a flow-through system. The minimum profitable tonnage was identified at 72 tons when selling catfish at the average price of R 56/kg. The optimal return on investment is achieved at 980 tons when selling at the identified average price.

8.3.5.2. Capital Expenditure

Table 8-12 below provides a summary of the infrastructure and built environment costs required to utilise flow-through systems for African sharptooth catfish production in South Africa.

Table 8-12: Flow-through System Capital Expenditure

Production Scale	Minimum 72 tons	Optimal 980 tons
Land Purchase	R 284 853	R 564 327
Infrastructure (Buildings)	R 1 393 570	R 3 859 980
Flow-through system	R 524 552	R 4 715 362
Additional equipment	R 231 182	R 984 696
Total Capital Expenditure	**R 2 455 159**	**R 10 175 046**

8.3.5.3. Operational Expenditure

Table 8-13 below provides a summary of the operational costs required for African sharptooth catfish production. The operational expenditure is shown for the first year of operation.

Table 8-13: Flow-through system Operational Expenditure for Catfish Production (Year 1)

Production Scale	Minimum 72 tons	Optimal 980 tons
Variable costs	**R 1 111 062**	**R 15 096 309**
Catfish fingerlings	*R 124 316*	*R 1 692 086*
Feed	*R 514 845*	*R 7 375 123*
Consumables – water quality	*R 10 800*	*R 147 000*
Fixed Costs	**R 1 611 395**	**R 11 281 033**
Total Operational Costs	**R 2 722 458**	**R 26 377 343**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of a flow-through operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed.

8.3.5.4. Flow-through System Financial Overview

Table 8-14 below provides an overview of the capital expenditure required, financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required, and the estimated number of employees required in the first year of production.

Table 8-14: Flow-through System Financial Overview

Production Scale	Minimum 72 tons	Optimal 980 tons
Financial Indicators		
Total Capital Expenditure	R 3 991 714,83	R 23 205 439,93
Loan Amount – Working Capital	R 1 536 556,20	R 13 030 393,99
Loam Amount - Infrastructure	R 2 455 158,62	R 10 175 045,94
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,01	15,88
Internal Rate Return (IRR)	7%	85%
Net Present Value over 10 years	R 4 012 552,52	R 368 588 159,56
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	1,2	2,3
Number of fingerlings required	6 906	94 005
Number of employees (Year 1)	8	43

The minimum profitable tonnage was identified at 72 tons per annum when selling the fish at R 56/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with flow-through system, with an estimated R 3 991 714 required to meet the minimum profitable tonnage, while the optimal production level of 980 tons per annum would require a capital investment of R 23 205 439 for a start-up producer. The costs associated with establishing and operating a flow-through system are namely operational costs linked with electricity and pumping requirements.

The flow-through system in the generic economic model includes RAS grow-out tanks for the 10 to 100-gram fish, and concrete/cement tanks for the 100 gram or larger fish.

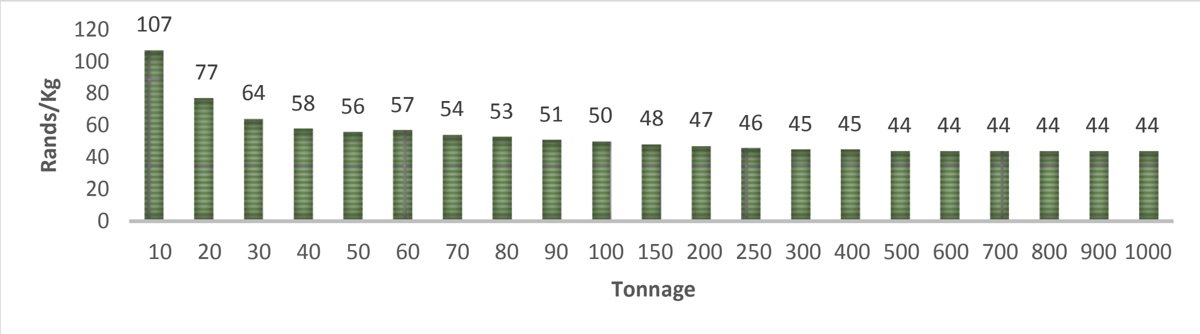
8.3.6. Raceway Systems

Raceway systems are assumed to operate in a similar manner to the RAS, with concrete tanks accommodated under tunnels to assist with heating and reducing electricity costs. A key challenge with raceways, as with the flow-through system, is identifying and accessing a suitable source of water that will be able to meet production needs. Without a reliable water source, extra consideration for water storage should be made, especially if proposing to implement a raceway system in dry regions or regions experiencing water shortages.

8.3.6.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price identified during the project was R35 per kilogram, however based on the generic economic model results, it is evident that at R35/kg, it would not be profitable for a start-up producer to produce Catfish. The graph below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-6: Raceway System: Selling Price vs Production Volumes



Source: Urban-Econ,2018

Based on the image above, it can be seen that the selling price for the African sharptooth catfish ranges from R 44/kg when producing 500 to 1000 tons per annum, to R 107/kg when producing 10 tons per annum. Based on the results above, the average selling price for catfish in South Africa was identified at R 53/kg when producing in a Raceway system. The minimum profitable tonnage was identified at 77 tons when selling catfish at the average price of R 54/kg. The optimal return on investment at the average selling price is achieved at 980 tons per annum.

8.3.6.2. Capital Expenditure

Table 8-15 below provides a summary of the infrastructure and built environment costs required to utilise raceways for African sharptooth catfish production in South Africa.

Table 8-15: Raceway Capital Expenditure

Production Scale	Minimum 77 tons	Optimal 980 tons
Land Purchase	R 281 976	R 418 952
Infrastructure (Buildings)	R 1 456 200	R 4 271 620
Raceway system	R 597 471	R 4 800 952
Additional equipment	R 329 264	R 1 633 485
Total Capital Expenditure	**R 2 689 912**	**R 11 271 209**

8.3.6.3. Operational Expenditure

Table 8-16 below provides a summary of the operational costs required for African sharptooth catfish production. The operational expenditure is shown for the first year of operation.

Table 8-16: Raceway Operational Expenditure for Catfish Production (Year 1)

Production Scale	Minimum 77 tons	Optimal 980 tons
Variable costs	**R 1 188 074**	**R 15 096 310**
Catfish fingerlings	*R 132 950*	*R 1 692 086*
Feed	*R 579 474*	*R 7 375 123*
Consumables – water quality	*R 11 550*	*R 147 700*
Fixed Costs	**R 1 644 905**	**R 10 877 120**
Total Operational Costs	**R 2 832 978**	**R 25 973 430**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of a raceway operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts.

8.3.6.4. Raceways Financial Overview

Table 8-17 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-17: Raceway Financial Overview

Production Scale	Minimum 77 tons	Optimal 980 tons
Financial Indicators		
Total Capital Expenditure	R 4 276 380,12	R 24 038 201,41
Loan Amount – Working Capital	R 1 586 467,76	R 12 766 992,08
Loam Amount - Infrastructure	R 2 689 912,37	R 11 271 209,33
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,00	13,84
Internal Rate Return (IRR)	7%	79%
Net Present Value over 10 years	R 4 281 389,75	R 332 590 644,73
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	1,1	1,7
Number of fingerlings required	7 386	94 005
Number of employees (Year 1)	8	43

The minimum profitable tonnage was identified at 77 tons per annum when selling the fish at R 53/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with a raceway system, with an estimated R 4 276 380 required to meet the minimum profitable tonnage, while the optimal production level of 980 tons per annum would require a capital investment of R 24 038 201 for a start-up producer.

The costs associated with establishing and operating a raceway system are namely operational costs linked with electricity, pumping requirements, and establishing tunnel infrastructure. The raceway system in the generic economic model includes RAS grow-out tanks for the 10 to 100-gram fish, and concrete/cement tanks for the 100 gram or larger fish.

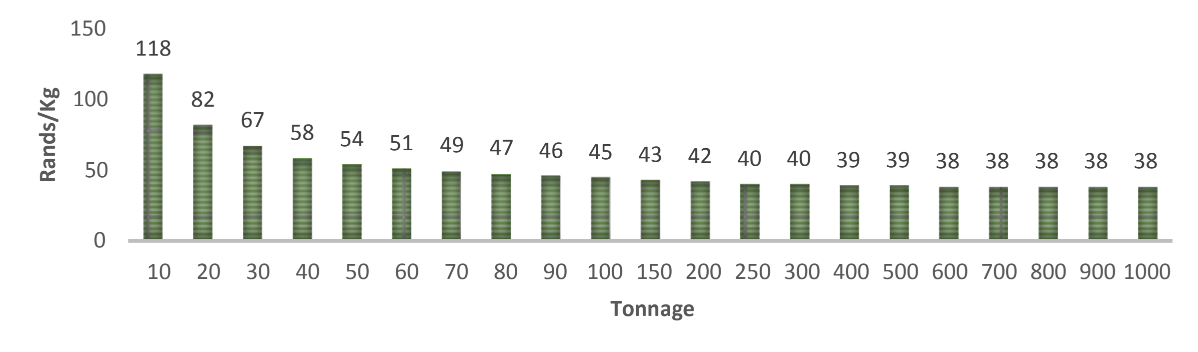
8.3.7. Aquaponics

Aquaponics is one of the more profitable production system, specifically as producers benefit from two income streams (vegetables and fish). The generic economic model is based on the production of leafy green vegetables (lettuce, spinach, pak choi and basil) as these are the easiest to grow in comparison to vegetables such as tomatoes, carrots etc. The aquaponics system typically operates as a RAS, using the same technology and operating system, however instead of circular tanks used for the RAS, linear tanks (as in the Flow-through system) were selected as this impacts on the type of grow beds used, and also ease of harvest of plants and fish. It was assumed that a producer would reuse 20% of the RAS water for aquaponics, however, the user can adapt this assumption in the model.

8.3.7.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price identified during the project was R35 per kilogram, however based on the generic economic model results, it is evident that at R35/kg, it would only be profitable to produce catfish in an aquaponics system with tonnages exceeding 400 tonnes per annum. The graph below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-7: African sharptooth catfish: Aquaponics Selling Price vs Production Volumes



Source: Urban-Econ,2018

Based on the figure above, it can be seen that the selling price for the African sharptooth catfish ranges from R 38/kg when producing 600 to 1000 tons per annum, to R 118/kg when producing 10 tons per annum. Based on the results above, the average selling price for catfish in South Africa was identified at R 50/kg when producing catfish an aquaponics system. Based on the results above, the minimum profitable tonnage identified was 64 tons per annum when applying the average price of R 50/kg. When selling the catfish at R 50/kg, the optimal production volume was identified at 924 tons per annum. Should a producer choose to increase the percentage (%) of water reuse, the amount of plants being produced and sold will increase, thus affecting the proposed selling price.

8.3.7.2. Capital Expenditure

Table 8-18 below provides a summary of the infrastructure and built environment costs required to utilise aquaponics for African sharptooth catfish production in South Africa.

Table 8-18: Aquaponics Capital Expenditure

Production Scale	Minimum 64 tons	Optimal 924 tons
Land Purchase	R 598 621	R 5 198 849
Infrastructure (Buildings)	R 2 027 996	R 13 896 562
Aquaponics system	R 1 491 687	R 17 617 307
Additional equipment	R 296 639	R 1 404 725
Total Capital Expenditure	**R 4 439 445**	**R 38 251 695**

8.3.7.3. Operational Expenditure

Table 8-19 below provides a summary of the operational costs required for Catfish production. The operational expenditure is shown for the first year of operation.

Table 8-19: Aquaponics Operational Expenditure for Catfish Production (Year 1)

Production Scale	Minimum 64 tons	Optimal 924 tons

Production Scale	Minimum 64 tons	Optimal 924 tons
Variable costs	**R 1 061 529**	**R 15 240 394**
Catfish fingerlings	*R 110 503*	*R 1 595 395*
Feed	*R 481 640*	*R 6 953 687*
Water quality Consumables	*R 9 600*	*R 138 600*
Seedlings	*R 68 289*	*R 985 929*
Hydroponic Grow Pots (annual replacement of 5%)	*R 1 138*	*R 16 432*
Fixed Costs	**R 1 366 172**	**R 7 599 925**
Total Operational Costs	**R 2 427 693**	**R 22 840 319**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of an aquaponics operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts. In addition to bulk feed prices, producers should identify bulk seedling suppliers, or alternatively investigate the feasibility of establishing their own growing facility for seedlings. Packaging and labelling required for the vegetables has not be included in the costing above, and should be considered by producers, specifically based on the target market requirements.

8.3.7.4. Aquaponics Financial Overview

Table 8-20 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-20: Aquaponics Financial Overview

Production Scale	Minimum 64 tons	Optimal 924 tons
Financial Indicators		
Total Capital Expenditure	R 5 818 451,76	R 49 196 939,89
Loan Amount – Working Capital	R 1 379 006,51	R 10 945 244,66
Loam Amount - Infrastructure	R 4 439 445,25	R 38 251 695,23
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1,02	9,23
Internal Rate Return (IRR)	7%	58%
Net Present Value over 10 years	R 5 953 087,74	R 453 904 446,33
Pay-back period (year)	20	20
Production Indicators		
Farm Size (hectares)	2,4	21
Number of fingerlings required	6 139	88 633
Number of employees (Year 1)	9	51

The minimum profitable tonnage was identified at 64 tons per annum when selling the fish at R 50/kg, which does exceed the typical farm-gate price of R15 – R 19/kg. It is important to consider the costs associated with flow-through system, with an estimated R 5 818 451 required to meet the minimum profitable tonnage, while the optimal production level of 924 tons per annum would require a capital investment of R 49 196 939 for a start-up producer. The costs associated with establishing and operating an aquaponics system are predominantly linked to the infrastructure development and operational costs of feed, and seedlings.

8.3.8. Financial Analysis Summary

Based on the financial analysis conducted for each of the six (6) production system above, it is evident that each system offers advantages and disadvantages for producers. The table below provides a high-level summary of the capital expenditure required for the minimum profitable tonnage, and the estimated return on investment.

Table 8-21: Summary: Production Systems Financial Overview

	RAS	Pond	Cage	Flow-Through	Raceways	Aquaponics
Tonnage	75	71	72	72	77	64
Selling Price	R 55/kg	R 48/kg	R 47/kg	R 56/kg	R 53/kg	R 50/kg
Capital Expenditure	R 3 937 448	R 4 691 795	R 4 245 235	R 3 991 714	R 4 276 380	R 5 818 451
IRR	8%	8%	8%	7%	7%	7%

From a financial aspect, it is clear that a flow-through system requires the lowest capital expenditure to establish at the minimum scale of 72 tons, however due to its high operational expenses, an average selling price of R 56/kg is required to be profitable.

Pond systems, aquaponics and raceways are the more expensive systems to establish initially, however, pond culture offers the lowest minimum production scale, and a more achievable average selling price than the other five systems. Aquaponics, although costly to establish and maintain offers producers two income streams (fish and vegetables) thus eventually it may be the most profitable option depending on the scale of plants being produced.

When selecting a production system, careful consideration is required not only for the site selection, but also establishing an off-take market that can pay producers the prices required for their operations to be profitable. The African sharptooth catfish generic economic model focused on primary production, however, producers should investigate not only catfish production, but also value-addition/processing activities as this would increase the revenue that can be achieved by a single producer.

8.4. Cost Benefit Analysis

Table 8-22 below shows a high-level cost benefit analysis for the African sharptooth catfish, based on the profitability index (PI) which is used as the cost benefit ratio. The analysis considers the six production systems, at the minimum profitable tonnage and optimal production volumes as identified in the section above.

Table 8-22: African Sharptooth Catfish Cost Benefit Analysis

	RAS	Pond	Cage	Raceway	Flow-through	Aquaponics
Minimum Profitable Tonnage						
Market price (R/kg)	R 55/kg	R 48/kg	R 47/kg	R 56/kg	R 53/kg	R 50/kg
Tons produced/annum	75	71	72	72	77	64
Profitability Index (PI)	1,03	1,09	1,07	1	1,01	1,02
Internal Rate of Return (IRR)	8%	8%	8%	7%	7%	7%
Employees required (Year 1)	8	7	8	8	8	9

Based on the table above, when considering the minimum profitable tonnage identified in the various systems, aquaponics is profitable at 64 tons per annum, which can be attributed to the two income streams associated with the system. Should a producer increase the amount of water being reused from month one (1), this system will be profitable at lower tonnages. The selling price of the catfish plays a major role in the profitability of an operation, which is illustrated above. Systems such as the RAS, Raceway and Flow-through have higher operating costs thus require higher selling prices in order to achieve a profit.

The Pond culture system offers the highest profitability index (PI) with 1,09 and an IRR of 8%, indicating a positive return on investment and profitable operation can be achieved when producing a minimum tonnage of 71 tons and selling at an average price of R 48 per kilogram.

Each system offers a number of employment, specifically at the higher tonnages, where more specialised and skilled employees can be used as the operation will be able to cover their salaries. At the lower tonnages, it is recommended that labour costs are kept to a minimum to ensure the operation is profitable, thus all systems offer between seven (7) and nine (9) jobs in year one of operation. The most labour-intensive systems at the higher tonnages, as seen in the table above include aquaponics, RAS, cage, raceways, and flow-through systems.

8.5. Best Case Scenario

Through the generic economic models, it is possible to look at "Best Case Scenarios" for each of the potential production systems at a provincial level. To do this, the following categories and criteria were used to assess the economic models.

I. **Selling weight:** Currently no minimum size has been identified for the African sharptooth catfish, as they are predominantly sold as a 1 kg fish. This analysis is based on African sharptooth catfish at 8 months old, weighing 1 kilogram.

II. **Minimum Tonnage required for each production cycle:** The minimum tonnage was identified to determine the minimum tonnage that an African sharptooth catfish producer needs to produce to be profitable. Profitability was measured by looking at the Profitability Index (PI), which should be one (1) or more.

III. **Price:** The farm gate price received for the African sharptooth catfish has a major impact on the profitability and sustainability of the aquaculture operation. The minimum recommended selling price differs for each production system and is affected by the annual production volume selected.

IV. **Finance Type:** The generic economic model provides three financing options for producers, however for this analysis the **debt/equity** finance option was selected with a 20% debt ratio. This assumes that a producer contributes 20% of their assets and receives funding for the remaining 80%.

When making use of the generic economic model for the African sharptooth catfish it should be noted that the figures and analysis discussed below are based at a provincial level and were obtained with the general assumptions used in the economic model. While at a provincial level a system and tonnage may show a positive return on investment or profitability index, this may differ at a site-specific level depending on the site temperatures and conditions, water quality and temperature, access to markets and access to input supplies, which all have a significant impact on the profitability and viability of an aquaculture operation.

All the provinces have been analysed from a financial viability aspect, however careful consideration of the environmental conditions and suitability of the province for African sharptooth catfish production must be taken before investing or proposing the establishment of a catfish producing operation.

The table below looks specifically at the average farm gate prices observed across the nine (9) provinces, as well as the minimum annual tonnage required to be profitable when selling the fish at the average farm gate price. As discussed earlier, these results are done using generic assumptions at a provincial level, and it should be expected that any analysis done at site specific aquaculture operations will differ according to the environmental conditions, site characteristics, as well as type of production system being used, and the size of fish being produced

Table 8-23: Average Farm Gate Price Best Case Scenario Summary

	RAS	Pond	Cage	Flow-through	Raceway	Aquaponics
EC	R 48/kg 77 tons	R 48/kg 71 tons	R 47/kg 72 tons	R 56/kg 72 tons	R 54/kg 73 tons	R 50/kg 64 tons
KZN	R 48/kg 77 tons	R 48/kg 71 tons	R 47/kg 72 tons	R 56/kg 72 tons	R 54/kg 73 tons	R 50/kg 64 tons
GP	R 48/kg 77 tons	R 48/kg 71 tons	R 47/kg 72 tons	R 56/kg 72 tons	R 54/kg 73 tons	R 50/kg 64 tons
WC	R 48/kg 77 tons	R 48/kg 71 tons	R 47/kg 72 tons	R 56/kg 72 tons	R 54/kg 73 tons	R 50/kg 64 tons
NC	R 48/kg 77 tons	R 48/kg 71 tons	R 47/kg 72 tons	R 56/kg 72 tons	R 54/kg 73 tons	R 50/kg 68 tons
LP	R 48/kg 32 tons	R 48/kg 35 tons	R 47/kg 31 tons	R 56/kg 30 tons	R 54/kg 31 tons	R 50/kg 40 tons
MP	R 48/kg 32 tons	R 48/kg 35 tons	R 47/kg 31 tons	R 56/kg 30 tons	R 54/kg 31 tons	R 50/kg 40 tons
NW	R 48/kg 32 tons	R 48/kg 35 tons	R 47/kg 31 tons	R 56/kg 30 tons	R 54/kg 31 tons	R 50/kg 40 tons
FS	R 48/kg 32 tons	R 48/kg 35 tons	R 47/kg 31 tons	R 56/kg 30 tons	R 54/kg 31 tons	R 50/kg 40 tons

Based on the table above, it can be seen that each system and province offers different average farm gate prices, and minimum annual tonnages required for an aquaculture operation to be profitable. When comparing the nine (9) provinces it is clear that producers located in Limpopo, Mpumalanga, the Free State and North West are profitable at much lower tonnages than the other provinces which can be attributed to the costs of electricity and need for heating. Systems such as raceways, RAS and flow-through indicate how temperature can impact on the profitability of an operation, as provinces that experience harsher climates or major seasonal temperature differences (such as the Northern Cape and KwaZulu-Natal) require additional heating and infrastructure such as tunnels to ensure production can occur year-round.

When comparing the pricing and tonnages above, it can be seen that aquaponics requires the highest production volume to be profitable which can be attributed to the high electricity consumptions, and capital expenditure required to establish the system. As mentioned previously, some provinces are not suitable for catfish production year-round due to low winter temperatures, specifically in the Eastern Cape escarpment, certain areas of the Free State, Northern Cape, Kwa-Zulu Natal and the Western Cape. Currently a major challenge for South African sharptooth catfish farmers is selling and marketing their produce, thus producers need to be very aware of their target market, the prices they can expect to receive, and what tonnage they need to be profitable based on the tables and analysis discussed in the section above.

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9. Conclusion and recommendations

This section provides conclusions and recommendations based specifically on the production aspect, including systems for African sharptooth catfish. In addition, recommendations based on the market assessment, and SWOT analysis are included.

9.1. Conclusion

The African sharptooth catfish is a good candidate species for aquaculture production. Biological characteristics such as air-breathing, tolerance of high-density stocking, hardiness, and fast growth make them ideal candidates for production in different culture systems in the temperate, water restricted South African climate. A major limitation to the commercial production of catfish is that currently, sharptooth catfish do not have a wide market acceptance when compared to other freshwater aquaculture species produced in South Africa. As a result, most of the producers in South Africa have shifted their production operations from growing fish to market size, to producing fingerlings for the export market. This shows that some work still needs to be done to develop the market for this fish in South Africa.

Six production systems were identified for the African sharptooth catfish in South Africa, which included the recirculating aquaculture system (RAS); aquaponics; cage culture; pond culture; and the flow-through system. The review of literatures shows that each of the applicable culture systems has some advantages and disadvantages as well as costs associated with certain technologies that are being utilised. As such, to reduce the costs and the likelihood of operating an unsuccessful production system, certain measures must be taken into consideration. This includes: ensuring good management practices, selection of a suitable production site (with appropriate climate, soil, topography, water quality and quantity, etc.), accurate system design, adequate skills, and training in operating the system, good marketing strategy; and sound product distribution logistics, etc. Furthermore, the following factors were identified as optimal operational requirements for sharptooth catfish aquaculture to be profitable:

- Hatchery (induced spawning),
- Fast growing strain,
- Suitable freshwater temperature,
- Access to high protein feeds,
- Economies of scale and consistent volume of production,
- Access to market (both formal and informal), and
- Some value addition (to make products more attractive to consumers).

When considering African sharptooth catfish production in South Africa, all six (6) production system prove to be economically viable at various production scales, and when selling the fish at different farm gate prices according to the province. It should be noted that production in Limpopo, Mpumalanga, the Free State, and the North West is more profitable at lower tonnages, and offers producers lower, more competitive average farm gate prices. All nine provinces show potential for catfish production; however, consideration should be made to ensure the province and site selected offers suitable environmental conditions, water resources and access to both formal and informal markets.

9.2. Recommendations

Based on the study conducted, the following recommendations have been made:

I. The African sharptooth catfish industry in South Africa needs to be re-established, as since 2010, there has been a decline in production, and a focus on producing fingerlings for export. The main issue identified was the low market prices received, which made production unfeasible. Improved communication is required between various government departments, relevant stakeholders, and producers to assess how the industry can be developed is required,

II. Support the development of the African Sharptooth catfish value chain, looking specifically at access to feed, feed costs and the quality of feed available in South Africa,

III. Input and equipment suppliers should be engaged with to ensure producers have access to all inputs and equipment required, as well as offer them a platform to discuss and negotiate bulk discount prices as economies of scale has a major impact on the development of an aquaculture operation,

IV. The African sharptooth catfish generic economic model should be updated annually to ensure the assumptions and costings are accurate. The updates will ensure the long-term use and sustainability of the generic economic model,

V. Develop strategic guidelines for African Sharptooth catfish production in South Africa. The guidelines should include information on:

  a. Production guidelines and information,
  b. Post Production and marketing regulations and standards,
  c. Permits and regulatory information (National and Provincial level),
  d. Environmental risks posed by the African Sharptooth catfish.

VI. Develop testing and regulatory standards and guidelines to align the South African catfish industry with the EU and USA market standards and regulations,

VII. Identify potential African markets to supply catfish to, and the required regulations or compliance required to supply these markets,

VIII. Support the continued development of the catfish processing industry in South Africa. Small-scale producers should be identified and supported to develop clusters. These clusters will improve the economies of scale and can be supported in the development of small-scale processing facilities which producers can supply,

IX. Streamline regulatory and permit application process. Clarification on the proposed amendments to the NEMBA AIS list to include Catfish must be finalised and communicated to all relevant stakeholders,

X. Research and development is required to improve the technology available to catfish producers in South Africa to reduce the capital and operational expenditure,

XI. Research and development is required to improve commercial catfish production. This can be done through case studies on existing catfish operations, as well as case studies on African catfish operations,

XII. Trials and pilot project on catfish production in the identified production systems should be conducted in different locations around South Africa to determine the optimal location for catfish aquaculture project, and

XIII. Marketing and consumer awareness on the consumption of catfish is critical to increase the consumption of catfish. Currently catfish has a negative market perception, thus the demand for catfish and prices received by producers remain low.

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